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VERIFICATION

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[Name of Document] SPECIFICATION

[Title of the Invention]

MAGNETIC HEAD, MAGNETIC DISK APPARATUS, AND INFORMATION RECORDING METHOD

[What is claimed is]

[Claim 1]

A magnetic disk apparatus comprising at least a recording magnetic head, a rotated magnetic disk, and a means for positioning said recording magnetic head relative to said rotated magnetic disk, wherein said recording magnetic head comprises a first magnetic pole and a second magnetic pole disposed respectively on the upstream side and downstream side with respect to the rotating direction of said magnetic disk, said first magnetic pole and said second magnetic pole have mutually faced portions, and said second magnetic pole is so shaped that, at a position on said magnetic disk where an angle between the rotating direction of said magnetic disk and the film thickness direction of said second magnetic pole is maximum, length of projection of said second magnetic pole onto the magnetic disk surface as measured along the radial direction of said magnetic disk is not more than a track pitch of said magnetic disk.

[Claim 2]

A magnetic disk apparatus comprising at least a

recording magnetic head, a rotated magnetic disk, and a means for positioning said recording magnetic head relative to said rotated magnetic disk, wherein said recording magnetic head comprises a first magnetic pole and a second magnetic pole disposed on the upstream side and downstream side with respect to the rotating direction of said magnetic disk, said first magnetic pole and said second magnetic pole are faced to each other, the faced surfaces of said first and second magnetic poles form a write gap, and a shape of said second magnetic pole has a third side between a first side intersecting said write gap and one of second sides faced to said write gap.

[Claim 3]

A magnetic disk apparatus comprising at least a recording magnetic head, a rotated magnetic recording medium, and a means for positioning said recording magnetic head relative to said rotated magnetic recording medium, wherein said recording magnetic head comprises a magnetic pole and an exciting coil, and said magnetic pole is so shaped that, at a position of angle S where an angle between the rotating direction of said magnetic disk and the film thickness direction of said magnetic pole is maximum, the sum of $P \times \cos(S)$ and $W \times \sin(S)$ (where W is a track width of said magnetic pole, and P is a magnetic pole thickness of said magnetic pole) is not more than a

track pitch of said magnetic disk.

[Claim 4]

A magnetic disk apparatus comprising at least a recording magnetic head, a rotated magnetic disk, and a means for positioning said recording magnetic head relative to said rotated magnetic recording medium, wherein said recording magnetic head comprises a first magnetic pole and a second magnetic pole disposed on the upstream side and downstream side with respect to the rotating direction of said magnetic disk, said first magnetic pole and said second magnetic pole have mutually faced portions, and said second magnetic pole is so shaped that, at a position of angle S on said magnetic disk where an angle between the rotating direction of said magnetic disk and the film thickness direction of said second magnetic pole is maximum, the sum of $P \times \cos(S)$ and $W \times \sin(S)$ (where W is a track width of said second magnetic pole, and P is a magnetic pole thickness of said second magnetic pole) is not more than a track pitch of said magnetic disk.

[Claim 5]

A magnetic disk apparatus as set forth in claims 1 to 4, wherein said magnetic disk apparatus is based on a longitudinal magnetic recording system.

[Claim 6]

A magnetic disk apparatus as set forth in claims 1

to 4, wherein said magnetic disk apparatus is based on a perpendicular magnetic recording system.

[Claim 7]

A magnetic head comprising a first magnetic pole, and a second magnetic pole faced thereto, wherein faced surfaces of said first and second magnetic poles form a write gap, a shape of said second magnetic pole has a third side between a first side intersecting said write gap and one of a pair of second sides faced to said write gap, and said third side is provided on the downstream side with respect to the running direction of a magnetic disk on which said magnetic head is mounted.

[Claim 8]

A magnetic head comprising a first magnetic pole, and a second magnetic pole faced thereto, wherein faced surfaces of said first and second magnetic poles form a write gap, a shape of said second magnetic pole has a third side between a first side intersecting said write gap and one of a pair of second sides faced to said write gap, and said third side is provided on the upstream side with respect to the running direction of a magnetic disk on which said magnetic head is mounted.

[Claim 9]

A magnetic disk apparatus comprising at least a recording magnetic head, a rotated magnetic disk, and a

means for positioning said recording magnetic head relative to said rotated magnetic disk, wherein said recording magnetic head comprises a first magnetic pole and a second magnetic pole disposed on the upstream side and downstream side with respect to the rotating direction of said magnetic disk, said first magnetic pole and said second magnetic pole have mutually faced portions, and said second magnetic pole is so shaped that, at a position on said magnetic disk where an angle between the rotating direction of said magnetic disk and the film thickness direction of said second magnetic pole is maximum, an overlapped portion of projection of said second magnetic pole onto the surface of said magnetic disk and the track width of said magnetic disk is more than 0% and not more than 5% of said track width.

[Claim 10]

A method of recording information wherein, at the time of modifying or appending information by using a magnetic disk apparatus, the modified or appended information is stored in a sector different from a sector in which previously recorded information is present, without overwriting a part or the entire body of said sector in which said previously recorded information is present.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Pertains]

The present invention relates to a magnetic storage device, particularly a magnetic disk apparatus and a magnetic head.

[0002]

[Prior Art]

Magnetic disk apparatuses are classified into a longitudinal magnetic recording system and a perpendicular magnetic recording system, according to the direction of magnetization of a magnetic film. The perpendicular magnetic recording system can easily realize higher recording density than the longitudinal magnetic recording system, and is expected to be put to practical use in the future. An example of such magnetic heads is seen, for example, in the Journal of the Magnetic Society of Japan, Vol. 19, Supplement No. S2, pp. 122-125. Further, time dependency of recorded magnetization in such magnetic recording films and effects of external magnetic field on the characteristics are described in, for example, IEEE Transaction on Magnetics Vol. 35, No. 5, pp. 2652 (1999) "Activation Volume and Correlation of Media Noise in High-Density Longitudinal Recording Media" or IEEE Transaction on Magnetics Vol. 35, No. 5, pp. 2655 (1999) "Rigid Disk Medium for 20 Gb/in2 Recording Demonstration".

[0003]

In both perpendicular magnetic recording and longitudinal magnetic recording systems mentioned above, magnetic heads having the same basic structures are used. A representative example of them will be described below referring to the part pertaining to the present invention.

[0004]

A general view of a rotary actuator with a magnetic head mounted thereon is shown in Fig. 1, and an enlarged view of the magnetic head portion 1 is shown in Fig. 2. Fig. 2 is a plan view as seen from above of the magnetic head 1. For positioning of the magnetic head 1 in a magnetic disk apparatus, the rotary actuator 2 is used. The angle formed by the rotating direction 4 of a magnetic disk 3 and the thickness direction 91 of magnetic pole (the direction of track width of magnetic pole in the magnetic disk surface) is defined as skew angle S. In the magnetic disk apparatus having the rotary actuator 2, the skew angle varies according to the position in the radial direction. Ordinarily, the skew angle S varies in a stroke range of about 20 degrees, according to the radial position.

[0005]

As seen in Fig. 2, the magnetic head 1 comprises a first magnetic pole 15, a recording magnetic pole 8 as a second magnetic pole, and a reproducing head portion 6.

The example shown in the figure is an example of ring head. The recording magnetic pole 8 has a film thickness 9 of the magnetic pole and a recording track width 7. In the case of a recording and reproducing head such as this example, a reproducing head 6 is disposed in stack with the recording head. Layout of a signal processing system and the like will be described later. In the following figures, the rotating direction of the magnetic disk is denoted by symbol 4, and the skew angle is denoted by symbol S.

[0006]

Attendant on the increase in the density of tracks in a magnetic storage device, the track width of magnetic heads has been made smaller and smaller. As the track width 7 of the recording head is reduced, it becomes difficult for a magnetic flux in the head to pass. Therefore, the recording magnetic pole of the head tends to be saturated easily, and leakage flux to a recording medium is reduced. In order to generate a magnetic field sufficient for recording information on the recording medium even under a narrow track condition, it is required to enlarge the magnetic pole thickness 8 of the recording head or to enhance saturation flux density of magnetic pole material for the recording head.

[0007]

[Problems to be Solved by the Invention]

The present invention provides a magnetic disk apparatus capable of securing a sufficiently stable recorded state even in magnetic recording with high record density.

[0008]

More particularly, from a technical aspect, the present invention solves the following difficulties. In the magnetic disk apparatus, at the time of recording information in an area where the above-mentioned skew angle is large, there is generated a condition where a magnetic field of a writing pole is applied to the information recorded in adjacent tracks adjacent to the writing track. By this condition, thermal decay of the recording medium at the track is accelerated. Over-writing the same track repeatedly results in further acceleration of the thermal decay of the recorded information. The present invention provides a magnetic head and a magnetic disk apparatus in which thermal relaxation of information recorded in adjacent tracks is not accelerated even in a region where the skew angle is large.

[0009]

Furthermore, the present invention proposes an information recording system such that thermal decay is not easily accelerated.

[0010]

[Means for Solving the Problems]

According to a first aspect of the present invention, there is provided a magnetic disk apparatus comprising at least a recording magnetic head, a rotated magnetic disk, and a means for positioning the recording magnetic head relative to the rotated magnetic disk, wherein the recording magnetic head comprises a first magnetic pole and a second magnetic pole disposed respectively on the upstream side and downstream side with respect to the rotating direction of the magnetic disk, the first magnetic pole and the second magnetic pole have mutually faced portions, and the second magnetic pole is so shaped that, at a position on the magnetic disk where an angle between the radial direction of the magnetic disk and the track width direction of the second magnetic pole is maximum, length of projection of the second magnetic pole onto the magnetic disk surface as measured along the radial direction of the magnetic disk is not more than a track pitch of the magnetic disk.

[0011]

According to another aspect of the present invention, there is provided a magnetic disk apparatus comprising at least a recording magnetic head, a rotated magnetic disk, and a means for positioning the recording magnetic head relative to the rotated magnetic disk, wherein the

recording magnetic head comprises a first magnetic pole and a second magnetic pole disposed on the upstream side and downstream side with respect to the rotating direction of the magnetic disk, the first magnetic pole and the second magnetic pole are faced to each other, the faced surfaces of the first and second magnetic poles form a write gap, and a shape of the second magnetic pole has a third side between a first side intersecting the write gap and one of second sides faced to the write gap.

[0012]

The third side is provided on the side of the second magnetic pole nearer to the write gap in one mode, and is provided on the side of the second magnetic pole farther from the write gap in another mode.

[0013]

Furthermore, the magnetic pole is so shaped that, at a radial position where an angle formed between the radial direction of the recording medium and the track width direction of the magnetic pole is maximum, length of projection of the magnetic pole onto the surface of the magnetic disk measured along the radial direction of the magnetic disk is not more than a track pitch of the magnetic disk.

[0014]

According to a further aspect of the present

invention, there is provided a magnetic disk apparatus comprising at least a recording magnetic head, a rotated magnetic recording medium, and a means for positioning the recording magnetic head relative to the rotated magnetic disk, wherein the recording magnetic head comprises a first magnetic pole and a second magnetic pole disposed on the upstream side and downstream side with respect to the rotating direction of the magnetic disk, and an exciting coil disposed between the first and the second magnetic pole, the first magnetic pole and the second magnetic pole are faced to each other, the faced surfaces of the first and second magnetic poles form a write gap, and a shape of the second magnetic pole has a pair of first sides intersecting the write gap, a pair of second sides substantially faced to the write gap, and a third side provided between one of the first sides and one of the pair of second sides substantially faced to the write gap.

[0015]

The third side is provided on the side of the second magnetic pole nearer to the write gap in one mode, and is provided on the side of the second magnetic pole farther from the write gap in another mode.

[0016]

Furthermore, the second magnetic pole is so shaped that, at a position where an angle formed between the

radial direction of the recording medium and the longitudinal direction of the second magnetic pole is maximum, the length of the projection of the second magnetic pole onto the surface of the magnetic disk measured along the radial direction of the magnetic disk is not more than the track pitch of the magnetic disk.

[0017]

As mentioned above, magnetic disk apparatuses are classified into a longitudinal magnetic recording system and a perpendicular magnetic recording system, and the present invention can basically be applied to both systems. This point is the same in the modes or embodiments of the present invention illustrated below.

[0018]

Besides, magnetic heads are classified into single-pole heads, ring heads and the like, and the present invention can be applied to both types of magnetic heads. This point is also the same in the modes or embodiments of the present invention illustrated below.

[0019]

According to a still further aspect of the present invention, there is provided a magnetic disk apparatus comprising at least a recording magnetic head, a rotated magnetic recording medium, and a means for positioning the recording magnetic head relative to the rotated magnetic

recording medium, wherein the recording magnetic head comprises a magnetic pole and an exciting coil, and the magnetic pole is so shaped that, at a position of angle S where an angle between the radial direction of the magnetic disk and the londitudinal direction of the magnetic pole is maximum, the sum of P × cos(S) and W × sin(S) (where W is a track width of the magnetic pole, and P is a magnetic pole thickness of the magnetic pole) is not more than a track pitch of the magnetic disk.

[0020]

According to a still further aspect of the present invention, there is provided a magnetic disk apparatus comprising at lest a recording magnetic head, a rotated magnetic recording medium, and a means for positioning the recording magnetic head relative to the rotated magnetic recording medium, wherein the recording magnetic head comprises a first magnetic pole and a second magnetic pole disposed on the upstream side and downstream side with respect to the rotating direction of the magnetic recording medium, the first magnetic pole and the second magnetic pole have mutually faced portions, and the second magnetic pole is so shaped that, at a position of angle S where an angle formed between the radial direction of the recording medium and the longitudinal direction of the second magnetic pole is maximum, the sum of P × cos(S) and W ×

sin(S) (where W is a track width of the second magnetic pole, and P is a magnetic pole thickness of the second magnetic pole) is not more than a track pitch of the magnetic recording medium.

[0021]

As these two modes of the invention of magnetic head as mentioned above, the following particular examples may be given. Namely, in the case of a ring type magnetic head, there may be used a method of adjusting the magnetic pole thickness of the second magnetic pole, and a method of shaping the second magnetic pole to reduce the projected length as compared with the case of the conventional magnetic pole thickness. As for the shaping of the second magnetic pole, there may be used a method of shaping a corner portion of the second magnetic pole nearer to the write gap, and a method of shaping the corner portion of the second magnetic pole farther from the write gap.

[0022]

Next, representative forms of a magnetic head according to the invention will be enumerated.

[0023]

A first form is a magnetic head comprising a first magnetic pole, a second magnetic pole faced thereto, and an exciting coil, wherein faced surfaces of the first and second magnetic poles form a write gap, and a shape of the

second magnetic pole has a third side between a first side intersecting the write gap and one of a pair of second sides substantially faced to the write gap.

[0024]

A second form is a magnetic head comprising a first magnetic pole, a second magnetic pole faced thereto, and an exciting coil, wherein faced surfaces of the first and second magnetic poles form a write gap, and a shape of the second magnetic pole comprises a pair of first sides intersecting the write gap, and a pair of second sides faced to the write gap, and further comprises a third side between one of the first sides and one of the pair of second sides faced to the write gap.

[0025]

The third side is provided on the side of the second magnetic pole nearer to the write gap in one mode, and is provided on the side of the second magnetic pole farther from the write gap in another mode. Of these modes, the former mode in which the third side is provided on the side nearer to the write gap is more useful in the case of a perpendicular magnetic recording system. The latter mode in which the third side is provided on the side farther from the write gap is more useful in the case of a longitudinal magnetic recording system. The difference between the two modes comes from the position of a

recording point of magnetic inversion in the two systems.

[0026]

Ordinarily, the shape of the first and second magnetic poles is basically a rectangle, and tetragons are often used. Naturally, in view of machining accuracy, a trapezoid and somewhat irregular tetragons or shapes with minute modifications may be used, which may basically be taken as rectangles. In the present specification, the shapes which may include such various modifications will be described as a geometrical shape, for example, a rectangle.

[0027]

The second side substantially faced to the write gap generally includes a side farther from the write gap and a side nearer to the write gap, and the present invention can be embodied using any one of the two sides. Based on basic thought of a plane surface shape in consideration of the above-mentioned machining strains and machining errors, the form can be said to basically adopt a pentagon.

[0028]

By use of a magnetic head having such a shape, the magnetic disk apparatus pertaining to the present application can easily be so constituted that, at a radial position where the angle formed between the radial direction of the magnetic disk and the track width direction of the second magnetic pole is maximum, the

length of the projection of the second magnetic pole onto the surface of the magnetic disk as measured along the radial direction of the magnetic disk is not more than the track pitch of the magnetic disk.

[0029]

The various forms of the present invention as enumerated above are the best examples for the objects of the present application. However, as the second best forms of the present invention, the following forms may also be adopted. Although these forms are inferior to the above-mentioned forms of the present invention with respect to basic thermal decay characteristics, they may be adopted according to required specifications of the device, and are excellent in the characteristics of thermal decay as compared with the magnetic disk apparatuses according to the prior art.

[0030]

According to a primary point of the mode of the present invention, there is provided a magnetic disk apparatus comprising at least a recording magnetic head, a rotated magnetic disk, and a means for positioning the recording magnetic head relative to the rotated magnetic disk, wherein the recording magnetic head comprises a first magnetic pole and a second magnetic pole disposed on the upstream side and downstream side with respect to the

rotating direction of the magnetic disk, the first and second magnetic poles have mutually faced portions, and the second magnetic pole is so shaped that, at a position where an angle formed between the radial direction of the magnetic disk and the track width direction of the second magnetic pole is maximum, the width of an overlapped portion of projection of the second magnetic pole onto the surface of the magnetic disk and the track width of the magnetic disk is more than 0% and not more than 10% of the track width. Further, the width of the overlapped area is preferably more than 0% and not more than 5% of the track width.

[0031]

The thought of the invention of the present application are illustrated by representative modes thereof, instead of enumerating all modes, and the thought of the invention of the present application is applied to the above-mentioned various modes of the invention. In any of the modes, an important point is a magnetic disk apparatus wherein the overlapped area of the projection of the magnetic pole onto the surface of the magnetic disk and the track width of the magnetic disk is more than 0% and not more than 10% of the track width. Further, the width of the overlapped area is preferably more than 0% and not more than 5% of the track width.

[0032]

Naturally, as mentioned above, the absence of the overlapped area of the projection of the magnetic pole onto the surface of the magnetic disk and the track width of the magnetic disk is the most excellent in view of thermal decay.

[0033]

Next, an information recording system in which thermal decay is not easily accelerated will be referred to. The method can suppress the acceleration of thermal decay attendant on appending of information onto a magnetic disk apparatus. Therefore, by using the method with the magnetic disk apparatus according to the present invention, the thermal decay at the time of recording on the magnetic disk apparatus can be suppressed, and the thermal decay on the magnetic disk apparatus attendant on repetition of recording can be effectively suppressed.

[0034]

The method comprises storing modified or appended information in a sector different from a sector with data recorded therein, without overwriting on a part or entire body of the sector with data recorded therein, at the time of modifying or appending information by use of the magnetic disk apparatus.

[0035]

[Mode for Carrying Out the Invention]

First, representative examples of constitution of a magnetic disk apparatus and a magnetic head according to the present invention will be described.

[0036]

Fig. 3 is a plan view showing general constitution of the magnetic disk apparatus, and Fig. 4 is a sectional view thereof. Fig. 4 is illustrative and is not an exact sectional view of the apparatus. Besides, the magnetic disk and the relationship between the magnetic disk and a rotary actuator and the like are basically the same as those shown in Fig. 1 and Fig. 2. Therefore, in the description of the present invention, the above-mentioned figures may sufficiently be taken in consideration.

[0037]

This example of the magnetic disk apparatus comprises a magnetic disk 3 with a magnetic recording medium mounted thereon, and a magnetic head 1 for carrying out recording and/or reproduction on the magnetic recording medium. The magnetic head 1 is positioned and mounted through the rotary actuator 2 and a suspension arm 50. The rotary actuator 2 performs rotational motion with a support point O as a center. The example shown in Fig. 1 is an example in which recording and reproduction are mounted on a single magnetic head. A magnetic induction type head is

used for a recording portion, and, for example, an MR head or the like is used for a reproducing portion. Ordinarily, the recording portion and the reproducing portion are provided as a laminate.

[0038]

As the magnetic recording medium in the case of longitudinal magnetic recording system, there are used, for example, cobalt-chromium based alloys such as cobalt-chromium alloys, cobalt-platium alloys, cobalt-chromium-tantalum alloys, cobalt-chromium-platinum alloys, cobalt-chromium- tantalum-platinum alloys or samarium-cobalt based alloys. As the recording medium in the case of perpendicular magnetic recording, there are used cobalt-chromium based alloys, terbium-iron-cobalt alloys and the like.

[0039]

A signal processing system is chiefly shown in Fig. 4. An electric signal sent to the magnetic head 1 through a head amplifier 15 is converted into magnetic information and recorded in the magnetic recording medium mounted on a rotated magnetic disk 3 by use of the magnetic head 1. At the time of reproduction, conversely, magnetic information recorded in the magnetic recording medium is converted into an electric signal by the magnetic head 1, and the converted information is transmitted to the head amplifier

15. The recording or reproduced signal is sent through the head amplifier 15 to a package board 16 on which a signal processing circuit and a controller are mounted. Positioning of the magnetic head 1 to a target track is carried out by the rotary actuator 2 driven by a voice coil motor 17. In Fig. 3, the upper side of the broken line is the enclosure side, and the lower side is the package board side. In the example shown, the magnetic disk 3 includes a first disk (3-1), a second disk (3-2) and a third disk (3-3). Symbol 4 in Fig. 3 and Fig. 4 denotes the rotating direction of the magnetic disk.

Fig. 5 is an enlarged view of an information recording/reproducing portion, Fig. 6A is a bottom view as viewed from a sliding surface of the magnetic head, and Fig. 6B is a vertical sectional view of the magnetic head. Referring to the figures, concrete constitution of the example of the magnetic head will be described. As mentioned above, the magnetic head 1 comprises as one body a recording head 5 having only a recording function, and a reproducing head 6 having only a reproducing function.

[0040]

As shown in Fig. 5, the recording head 1 comprises a recording magnetic pole 8 and an upper shield film 19, with a coil 18 sandwiched therebetween. The upper shield film 19 functions also as a first magnetic pole. Naturally, the

shield and the first magnetic pole may be provided as separate bodies. By generating an alternating recording current in the coil 18, an alternating magnetic field is generated between the recording magnetic pole 8 and the upper shield 19, whereby magnetic information is recorded on the magnetic recording medium. In Fig. 6B, the magnetic field 51 is shown schematically.

[0041]

The reproducing head 6 is sandwiched between the upper shield 19 and a lower shield film 20, whereby leakage flux from the neighborhood is shielded, and only the information directly beneath the target position can be reproduced easily. Symbol 21 denotes an electrode of the reproducing head, and a layer 23 is the reproduction gap (Fig. 6A and Fig. 6B). The form of this example is now widely used for magnetic heads. An insulation film, for example, an alumina layer 22 is provided between a first magnetic pole (functioning also as upper shield) 19 and a second magnetic pole (recording pole) 8. The first magnetic pole (upper shield) 19, the insulation film 22, and the second magnetic pole coil (recording pole) 8 are laminated, and one side of the laminate constitutes a sliding surface. As shown in Fig. 6B, the magnetic head 1 is faced to the magnetic disk 3. Therefore, the portion of the insulation film 22 constitutes a write gap. The

magnetic disk 3 comprises a recording medium layer 25 laminated on a substrate 24.

[0042]

Although the present invention is naturally useful for magnetic disk apparatuses in general, it is particularly useful for a magnetic disk apparatus designed for a high record density of not less than 10 Gbit per square inch. Naturally, this is due to the fact that the track width is smaller than the conventional values. Generally, the pole thickness of the second magnetic pole may be several micrometers, and, usually, 3 to 4 μm. The thickness of the first magnetic pole also is about several micrometers. As the track width, a value of about 50 to 80% of the track pitch is adopted. Naturally, these specific values are determined according to required specifications of the magnetic disk apparatus.

[0043]

Next, positional relationship of the magnetic head and recording tracks according to the invention will be described. Fig. 7, Fig. 8 and Figs. 11 to 13 show positional relationship of magnetic pole, recording track and adjacent tracks, as viewed from above. In addition, rotating direction and radial direction of the disk are also shown. In these figures, the same components or members are denoted by the same symbol; accordingly,

individual descriptions may be omitted for each of the figures. Furthermore, Fig. 9 and Fig. 10 show examples of recording magnetic field distribution at a central portion and an end portion of track.

[0044]

Fig. 7 shows the positional relationship between a magnetic head and recording tracks according to a first embodiment of the invention. The figure shows the positional relationship, as viewed from above, of a data track 10 and adjacent tracks 11, 12 in the case where the skew angle is S. A track pitch is denoted by numeral 13. As the magnetic head, only a first (lower) pole 15 and a second (upper) pole 9 are illustrated. The areas of symbols 10', 11' and 12' in the figure are areas of inversion of magnetization corresponding to tracks in a recording medium layer. This applies also in the similar figures below.

[0045]

In the present example, projected length 14 of the upper pole 9 in the radial direction of disk is set to be not more than the track pitch. For this purpose, as shown in Fig. 7, an end portion of the upper pole 9 is cut away so that the magnetic pole of the recording head does not overlap on the adjacent track portion.

[0046]

More concrete description will be given below. The magnetic head for recording in this example comprises a first magnetic pole 15 and a second magnetic pole 9 disposed on the upstream side and downstream side with respect to the rotating direction of the magnetic disk. The first and second magnetic poles are faced to each other, and a portion between the faced surfaces 30, 31 of the first magnetic pole 15 and the second magnetic pole 9 constitutes a write gap 36. The second magnetic pole 9 has a third side 34 between a first side 35 intersecting the write gap 36 and one 33 of second sides (31, 33) faced to the write gap 36. Thus, the second magnetic pole 9 is so shaped that, at a position where an angle (S) formed between the radial direction of the magnetic disk and the longitudinal direction of the second pole 9 is maximum, length 14 of projection of the second pole 9 onto the surface of the magnetic disk (namely, projected length) is not more than a track pitch 13 of the magnetic disk. According to this arrangement, acceleration of thermal decay due to a head field does not occur. To ensure that, at the position where the angle formed between the radial direction of the magnetic disk and the longitudinal direction of the magnetic pole is maximum, the length of the projection of the magnetic pole onto the surface of the magnetic disk as measured along the radial direction of the

magnetic disk is not more than the track pitch of the magnetic disk, an end portion of the upper pole 16 is cut away, and the degree of cutting away is set in consideration of the field intensity required for recording.

[0047]

In this example, the third side 34 is provided on the side of the magnetic head farther from the write gap.

[0048]

Naturally, the present invention can be applied to various recording heads and magnetic disk apparatuses other than the illustrated here.

[0049]

The ring type magnetic head can be used for both longitudinal magnetic recording and perpendicular magnetic recording, and spacing of the write gap and other characteristics are selected according to the differences in the recording systems. A comparatively narrower write gap is used for the longitudinal magnetic recording, and a comparatively wider write gap is used for the perpendicular magnetic recording. In the perpendicular magnetic recording, of magnetic lines of force from the write gap, a perpendicular component relative to the recording medium surface is utilized. Therefore, designing of the magnetic head, particularly the write gap, is so conducted that the perpendicular component of the head field is principally

generated on the surface of the recording medium. On the other hand, in the longitudinal magnetic recording, of magnetic lines of force from the write gap, a parallel component relative to the recording medium surface is utilized. Therefore, designing of the magnetic head, particularly the write gap, is so conducted that the parallel component of the head field is principally generated on the surface of the recording medium. Accordingly, the magnetic heads according to the invention particularly suited to both recording systems are designed differently depending on the system. As shown in Fig. 15, a large longitudinal component of head field is present at the write gap portion in the case of the longitudinal magnetic recording, whereas a large perpendicular component of head field is present throughout the magnetic pole in the case of the perpendicular magnetic recording. Therefore, inversion of magnetization recorded finally on the medium is located at the write gap portion in the case of the longitudinal magnetic recording, whereas it is located at an end portion on the trailing side of the upper pole or main pole in the case of the perpendicular magnetic recording.

[0050]

The characteristic feature pertaining to the gist of the invention is that, at a radial position where the angle

formed between the radial direction of the magnetic disk and the track width direction of the second magnetic pole is maximum, the length of the projection of the second magnetic pole onto the surface of the magnetic disk measured along the radial direction of the magnetic disk is not more than the track pitch of the magnetic recording medium, and an attentional basic portion in realizing the characteristic feature in view of the above-described background is as follows. The portion to be paid attention to is a portion of the second magnetic pole farther from the write gap in the case of the longitudinal magnetic recording, and a portion of the second magnetic pole nearer to the write gap in the case of the perpendicular magnetic recording. From this point of view, Fig. 7 shows an embodiment particularly suitable for the longitudinal magnetic recording, while Fig. 12 shows an embodiment particularly suitable for the perpendicular magnetic recording.

[0051]

As a magnetic head, the above-mentioned single pole type head is suited to the perpendicular magnetic recording.

[0052]

Next, the effects of the present invention will be described.

[0053]

Fig. 8 is the same as Fig. 7 in constitution but differs from Fig. 7 in that the thought of the present invention is not applied to the upper magnetic pole 16. In this example, the projection of the second magnetic pole on the track surface overlaps on the track adjacent to the data track. Namely, where the pole thickness 8 of the recording head is large, a portion of a tip of the write pole 9 has an overlap 17 on the position of the adjacent track 12 when the skew angle is large. For example, in the case of a rectangular write pole where the track pitch 13 is 1.3 micrometers, the write track width 7 is 1 micrometers and the pole thickness 8 is 3 micrometers, a portion of the upper magnetic pole 9 overlaps on the position of the adjacent track 12 in an area where the skew angle is not less than 5.8 degrees.

[0054]

Calculation results of distribution of write field generated from a ring type recording head are shown in Figs. 9 and 10. Fig. 9 and Fig. 10 show calculation results of write field distribution at a track center portion and a track end portion, respectively. Here, x-axis is the direction 4 of the magnetic disk, and y-axis is the track width direction. Besides, x-component and y-component of the write field are defined as Hx and Hy, respectively. In each of Figs. 9 and 10, layout of lower pole, write gap and

upper pole is shown at the upper portion, distribution of magnetic field (Hy) in y-direction is shown in the intermediate graph, and distribution of magnetic field (Hx) in x-direction is shown in the lower graph.

[0055]

As seen from Fig. 9, at the track center, Hx is maximum at the position directly beneath the gap 13, and has an intensity distribution along the x-axis direction; the intensity decreases rapidly as the distance from the gap increases. The value of Hy is substantially 0 at any position. As seen from Fig. 10, at the track end also, Hx is maximum at the position directly beneath the gap 13, and decreases rapidly as the distance from the gap increases. On the other hand, as contrasted to the case of the track center, Hy gradually trails and has a value of about several hundred oersted until the tip portion of the upper magnetic pole is reached. As a result, in the area where the skew angle is large, a magnetic field at the time of recording information is applied also to the data previously recorded in the adjacent track. For example, at the track end portion, there is a magnetic field of 230 Oe at the end point A of the upper magnetic pole. Where one half of the upper magnetic pole overlaps on the adjacent track, it is seen from Fig. 10 that the magnetic field at the point of (A + B)/2, namely a field of 810 Oe at maximum

is applied to the adjacent track. Where 1/3 of the upper magnetic pole overlaps on the adjacent track, the magnetic field at the point of (2A + B)/3 in Fig. 10, namely a field of 620 Oe at maximum is applied to the adjacent track.

[0056]

In magnetic disks, a phenomenon of disturbance of recorded state, and a reduction of reproduction amplitude with time, under the effect of the phenomenon of thermal relaxation of recorded data (hereinafter referred to as thermal decay) has been reported, as mentioned above.

[0057]

This is due to change of the recorded state by thermal energy at an ambient temperature for a recording medium. The presence of an external field gives energy to individual crystal grains, like heat, and therefore accelerates the thermal decay.

[0058]

Magnetization recorded on a magnetic disk suffers thermal relaxation, and remnant magnetization decreases with time. It has been described that the thermal relaxation is accelerated by the presence of an externally applied magnetic field. A simulation of a magnetic recording has been done by use of the Landau-Lifschitz equation, and applied field dependency of the remnant magnetization after 10 years has been calculated. The

results are shown in Table 1.

[0059]

Table 1

Table 1

Effective field Applied to Adjacent track (Oe)	Theoretical value of remnant magnet-zation after 10 years (relative value)	Note
0	0.97	Upper pole does not overlap on adjacent track
200	0.955	
220	0.95	
620	0.90	1/3 of upper pole overlaps on adjacent track
810	0.86	1/2 of upper pole overlaps on adjacent track

[0060]

The magnetic field applied to the adjacent track is 230 Oe when the end point A of the upper pole is in contact with the adjacent track, 620 Oe when 1/3 of the upper pole overlaps on the adjacent track, and 810 Oe when 1/2 of the

upper pole overlaps on the adjacent track. In view of Table 1 showing the relative value of remnant magnetization after 10 years, the remnant magnetization is reduced to 0.86 when one half of the upper pole overlaps on the adjacent track, and is reduced to 0.90 when 1/3 of the upper pole overlaps on the adjacent track.

[0061]

In order to prevent a floating magnetic field from being applied to the adjacent track at a radius where the skew angle is maximum, it suffices that the projected length 14 of the upper pole in the radial direction of the disk as shown in Fig. 8 is not more than the track pitch 13. Therefore, when the end portion 17 of the upper pole is cut away as described above so that the magnetic pole of the recording head does not overlap on the adjacent track, acceleration of thermal decay by head field will not occur.

[0062]

Fig. 11 shows a second embodiment of the present invention. This embodiment shows another example of preventing the projection 14 of the magnetic pole 9 of the recording head from overlapping on the adjacent track portion 12. For ensuring that the projected length of the upper pole is not more than the track pitch, in the same manner as in the first embodiment, it suffices that the shape of the ordinary rectangular upper pole satisfies the

following formula:

[0063]

$$TP \geqq P \times \sin(S) + W \times \cos(S)$$

Where TP is the track pitch, P is the pole thickness of the upper magnetic pole, W is the track width of the recording head, and S is the skew angle of the magnetic head.

[0064]

This example differs from the example of Fig. 7, and is not an example in which the shape of the second magnetic pole is defined by use of a third side. The shape of the second magnetic pole is tetragonal and the pole thickness thereof is controlled. The same idea may be used also in the case of a single pole form.

[0065]

Fig. 12 shows a third embodiment of the present invention. In the same manner as in the first embodiment, for ensuring that the projected length 14 of the upper magnetic pole 9 is not more than the track pitch 13, an end portion of the upper magnetic pole is cut away. While in the first embodiment the end portion of the upper magnetic pole 9 on the downstream side with respect to the rotating direction of the disk was cut away, in this embodiment an end portion on the side of the gap 36 is cut away. A side 37 is a third side.

[0066]

As has been described above, at the time of recording a magnetization inversion by a magnetic head on a rotated disk, the position at which the magnetization inversion is finally determined is substantially directly beneath the gap in the longitudinal magnetic recording system, but it is near a faced line of the upper magnetic pole farther from the gap in the perpendicular magnetic recording system. This embodiment can be applied to not only the longitudinal magnetic recording system but also the perpendicular magnetic recording system.

[0067]

Fig. 13 shows a fourth embodiment of the present invention. This embodiment differs from the second embodiment shown in Fig. 11 only in that a recording point of magnetization inversion is shifted.

[0068]

This embodiment can be applied to not only the longitudinal magnetic recording system but also the perpendicular magnetic recording system.

Next, the perpendicular magnetic recording, particularly an example of the perpendicular magnetic recording with a bi-layer medium will be described.

[0069]

This case requires more the present invention, and

this example is an example for which the effects of the present invention are displayed more effectively.

[0070]

Magnetic recording with a bi-layer medium means that a recording medium is constituted of two layers of recording material. As shown in Fig. 14, a magnetic disk generally comprises on a disk substrate 40 a ground layer 41, a chromium alloy layer 42, a magnetic recording layer 43 and an upper protective film 44. The constitution of the laminate may be improved or modified variously, but the basic constitution is as described above. For example, the chromium alloy layer 42 may be omitted. Examples of the material for the magnetic recording layer has been described above, and the bi-layer medium may comprise, for example, a soft magnetic film 46 or the like beneath a first magnetic recording layer 45. Since this technology itself is well known, detailed description thereof is omitted.

[0071]

Fig. 15 shows an example of distribution of recording field under the recording gap and magnetic poles in a ring head. Layout of the recording gap and magnetic poles is shown in an upper portion of the figure, a longitudinal field component of head field at the time of recording on a longitudinal magnetic recording medium is

shown in an intermediate portion of the figure, and distribution of a perpendicular field component at the time of recording on a bi-layer perpendicular magnetic recording medium is shown in a lower portion of the figure. In this example, the distribution of the longitudinal field component at the time of recording on the longitudinal magnetic recording medium is the same as the examples described above. On the other hand, the distribution of the perpendicular field component at the time of recording on the bi-layer perpendicular magnetic recording medium is different from the above examples in that the area with a large perpendicular field component extends below the magnetic poles.

[0072]

On the other hand, in the case of a general magnetic head, for example, the example of Fig. 10, the distribution of Hy has a maximum value at an end portion of the write gap, and the perpendicular field component gradually decreases as the end of the magnetic pole is approached. At the end portion of the magnetic pole, no large component exists.

[0073]

Due to such a difference in magnetic field distribution, in this example of the bi-layer medium there is a stricter requirement as to the setting of distance

between the recording pole and the adjacent track. Namely, in the perpendicular magnetic recording on the bi-layer medium, the influence of the magnetic pole on the adjacent track is greater than that in ordinary cases. Even a small degree of overlap of the magnetic pole on the adjacent track would cause great acceleration of thermal decay. Accordingly, the effect of applying the present invention is more conspicuous in such an example of the bi-layer medium.

[0074]

Next, an example of the method of producing the magnetic head according to the invention will be described.

[0075]

Figs. 16A to 19B are plan views illustrating major points of the method of producing the magnetic head according to the invention. In these figures, like the above examples, an example of a ring head is treated, and only projections of a first magnetic pole 15 and a second magnetic pole 9 onto the disk surface are shown. The major point of the method of producing a magnetic disk according to the invention relates to processing of the plan shape of the magnetic pole, and only the steps of this process are illustrated.

[0076]

Ordinarily, as shown in Fig. 6, components from a

lower shield film 20 to a recording magnetic pole 8 are sequentially provided on a non-magnetic substrate. After the recording pole 8 is formed as a film, an end face on the rear end side of the recording pole 8 is flattened so as to be parallel to a reproducing head or the like. The flattening is carried out by lapping, FIB (Focussed Ion Beam) processing or the like. According to the present invention, an ordinary rectangular upper pole is formed by such conventional method, and thereafter a desired portion the projection of which overlaps on the adjacent track is removed. For the removal, there may be used FIB, sputtering, ion milling and the like. The working conditions for these processes may be as in the usual cases for the material related.

[0077]

Figs. 16A, 16B, 17A and 17B show an example of removing a corner portion of the second magnetic pole farther from the write gap, whereas Figs. 18A, 18B, 19A and 19B show an example of removing a corner portion of the second magnetic pole nearer to the write gap. Numerals 34 and 37 denote a third side.

[0078]

Fig. 16A is a plan view of a magnetic pole formed by a prior-art method. A box-shaped area shown in Fig. 16A is trimmed by FIB from the head floating side, to produce the

shape shown in Fig. 16B.

[0079]

Figs. 17A and 17B show a second method of producing the magnetic head used in the first embodiment of the invention. Fig. 17A is a plan view of a magnetic pole formed by a prior-art method. As shown in Fig. 17A, Ar sputtering or ion milling is carried out in a skew direction to produce the shape shown in Fig. 17B. In this case, the sputtering or ion milling is preferably carried out in a skew direction of less than 90 degrees with respect to the track width direction.

[0080]

Figs. 18A and 18B show another method of producing the magnetic head for use in the third embodiment of the invention. Fig. 18A is a plan view of a magnetic pole formed by a prior-art method. A box-shaped area shown in Fig. 18A is trimmed by FIB from the head floating side, to produce the shape shown in Fig. 18B.

[0081]

Figs. 19A and 19B show a further method of producing the magnetic head for use in the third embodiment of the invention. Fig. 19A is a plan view of a magnetic pole formed by a prior-art method. As shown in Fig. 19A, Ar sputtering or ion milling is carried out in a skew direction to produce the shape shown in Fig. 19B. In this

case, the sputtering or ion milling is preferably carried out in a skew direction of less than 90 degrees with respect to the track width direction.

[0082]

In this method, the lower magnetic pole may be a little machined away, depending on the sputtering or milling conditions. In this method, therefore, it is preferable to control, for example, power condition so that the lower magnetic pole would not greatly machined away.

[0083]

Next, another example of the present application will be described. Fig. 21, like similar figures described above, shows a positional relationship of a magnetic pole, recording track (data track) and adjacent tracks in this example, as viewed from above.

[0084]

The second magnetic pole is so shaped that, at a position where an angle formed between the radial direction of the magnetic disk and the longitudinal direction of the second magnetic pole is maximum, an overlapped portion 18 of projection of the second magnetic pole 19 onto the surface of the magnetic disk and a track width 12′ of the magnetic disk is not more than 10% of the track width 12′. More preferably, the overlapped portion is in excess of 0% but not more than 10% of the track width, whereby the

magnetic head obtained shows more excellent characteristics than the conventional magnetic heads. In this example, the third side 34 is used, and the projection of the second magnetic pole 9 onto the track surface overlaps on the track 12 adjacent to the recording track (data track) 10.

[0085]

The invention can be accomplished with single-pole magnetic heads or ring heads, irrespectively of the shapes of magnetic poles, by ensuring that the overlapped portion of the projection of the magnetic pole onto the surface of the magnetic disk and the track width of the magnetic disk is set within a predetermined range. While these points of the present invention will not be illustrated more, the present invention can naturally be embodied with the magnetic poles having the shapes shown in Figs. 7, 11, 12 and 13. Such magnetic poles can be produced in the same manner as the above-mentioned methods.

[0086]

Next, a method of modifying or appending information on a magnetic disk apparatus will be described.

[0087]

Fig. 21 shows a method of modifying or appending information on a magnetic disk apparatus according to the present invention. In an upper portion of Fig. 21, a recorded state before data are modified or appended is

shown. The figure shows that the data are recorded on only a data block 1. When a composition is modified or appended on a word processor, if recording or reproduction for repeated overwriting is repeated only on the data block 1 in which data are previously recorded, only the same portions of the adjacent tracks are repeatedly affected by a floating field of recording. In order to alleviate such a situation, at the time of overwriting, the entire data in the data block requiring overwriting are recorded on a data block (for example, data block 2) other than the previous data block. As a result of this process, the situation in which the floating field at the time of recording is repeatedly applied to the adjacent track at each overwriting can be obviated, and acceleration of thermal decay can be suppressed.

[0088]

[Effects of the Invention]

The present invention can provide a magnetic disk apparatus capable of securing a sufficiently stable recorded state even in magnetic recording with high recording density.

[0089]

From a technical point of view, the present invention can provide a magnetic head and a magnetic disk apparatus such that thermal relaxation of recorded data in

adjacent tracks is not accelerated even in an area where a skew angle is large.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a partial general view of a magnetic disk apparatus.

[Fig. 2]

Fig. 2 is an enlarged plan view of a magnetic head portion.

[Fig. 3]

Fig. 3 is a plan view showing general constitution of a magnetic disk apparatus.

[Fig. 4]

Fig. 4 is a sectional view showing general constitution of a magnetic disk apparatus.

[Fig. 5]

Fig. 5 is a perspective view of a recording/reproducing portion.

[Fig. 6A]

Fig. 6A is a bottom view as viewed from a sliding surface of a recording/reproducing portion of a magnetic head.

[Fig. 6B]

Fig. 6B is a vertical sectional view of a recording/reproducing portion of a magnetic head.

[Fig. 7]

Fig. 7 is a plan view showing a positional relationship between a magnetic head and write tracks according to a first embodiment of the invention.

[Fig. 8]

Fig. 8 is a plan view showing a positional relationship between a magnetic head and write tracks illustrating the problem in the prior art.

[Fig. 9]

Fig. 9 is a diagram illustrating an example of magnetic field distribution at the center of track in a ring type magnetic head.

[Fig. 10]

Fig. 10 is a diagram illustrating an example of magnetic field distribution at an end portion of a track in the ring type magnetic head.

[Fig. 11]

Fig. 11 is a plan view showing positional relationship between a magnetic head and write tracks according to a second embodiment of the invention.

[Fig. 12]

Fig. 12 is a plan view showing positional relationship between a magnetic head and write tracks according to a third embodiment of the invention.

[Fig. 13]

Fig. 13 is a plan view showing positional relationship between a magnetic head and write tracks according to a fourth embodiment of the invention.

[Fig. 14]

Fig. 14 is a sectional view showing an example of lamination of a magnetic recording medium.

[Fig. 15]

Fig. 15 is a diagram showing an example of magnetic field distribution in the case of using a bi-layer perpendicular magnetic recording medium with a ring type magnetic head.

[Fig. 16A]

Fig. 16A is a plan view of a magnetic pole before machining formed by a prior-art method.

[Fig. 16B]

Fig. 16B is a plan view of an example of a magnetic pole after machining.

[Fig. 17A]

Fig. 17A is a plan view of a magnetic pole before machining formed by a prior-art method.

[Fig. 17B]

Fig. 17B is a plan view of an example of a magnetic pole after machining.

[Fig. 18A]

Fig. 18A is a plan view of a magnetic pole before

machining formed by a prior-art method.

[Fig. 18B]

Fig. 18B is a plan view of an example of a magnetic pole after machining.

[Fig. 19A]

Fig. 19A is a plan view of a magnetic pole before machining formed by a prior-art method.

[Fig. 19B]

Fig. 19B is a plan view of an example of a magnetic pole after machining.

[Fig. 20]

Fig. 20 is a diagram illustrating a data modifying/appending system for a magnetic disk apparatus according to the invention.

[Fig. 21]

Fig. 21 is a plan view showing positional relationship between a magnetic head and write tracks according to a further embodiment of the invention.

[Explanation of Symbols]

1: magnetic head; 2: rotary actuator; 3: magnetic disk; 4:rotating direction of magnetic disk; 5: recording head; 6: reproducing head; 7: write track width; 8: pole thickness; 9: upper pole; 10: data track; 11: adjacent track; 12: track pitch; 13: write gap; 14: projected length of upper pole in radial direction of disk.

[Name of Document] ABSTRACT

[Summary]

[Object]

The present invention provides a magnetic head and a magnetic disk apparatus such that thermal relaxation of data recorded in adjacent tracks is not accelerated even in an area where a skew angle is large.

[Solving Means]

A representative means according to the present invention ensures that a shape of an upper pole is so shaped that, at a position where a skew angle is maximum, the maximum value of the projected length of the upper pole in the radial direction of disk is not more than a track pitch.

[Selected Drawing] Fig. 7

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FIG. 1

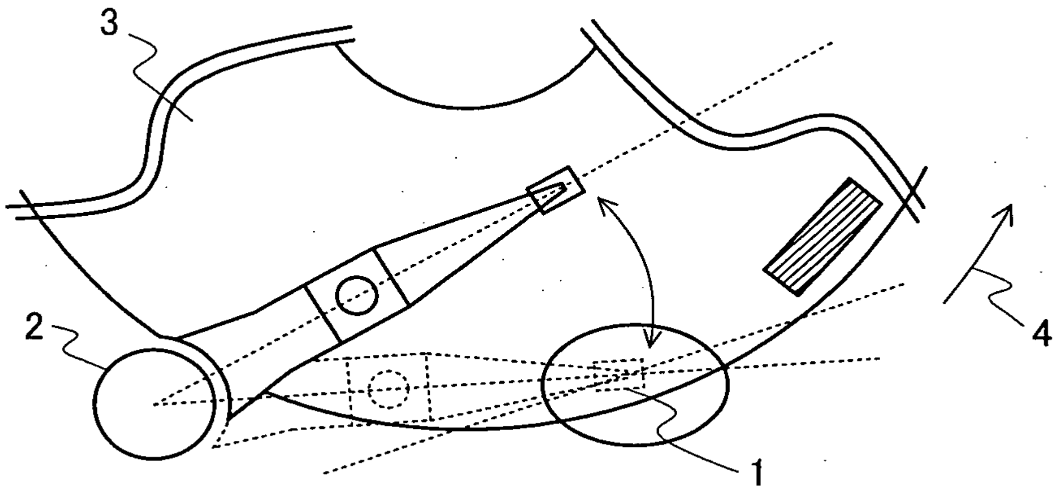


FIG. 2

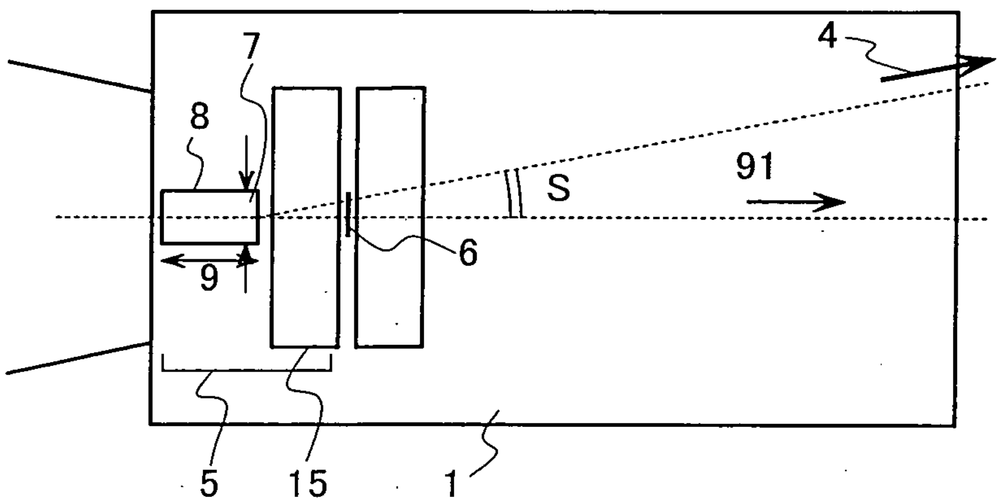


FIG. 3

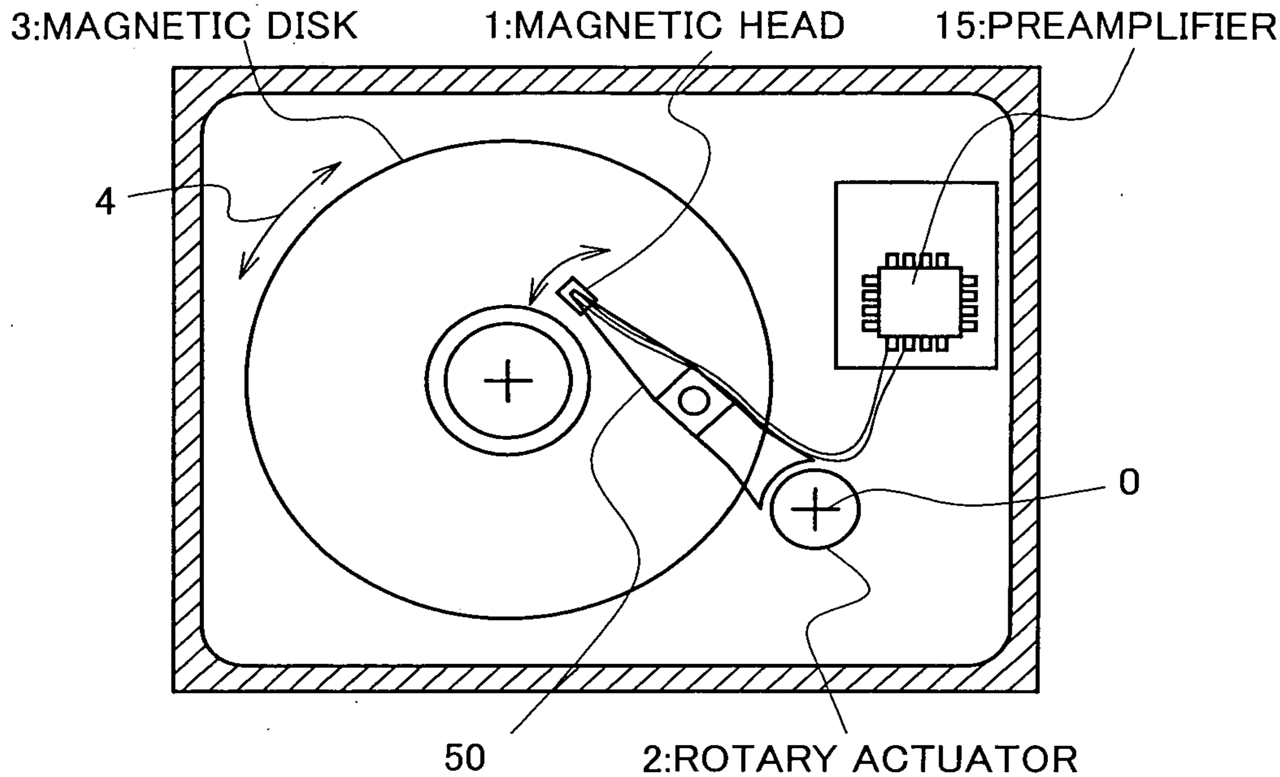

3:MAGNETIC DISK
1:MAGNETIC HEAD
15:PREAMPLIFIER
4
0
50
2:ROTARY ACTUATOR

FIG. 4

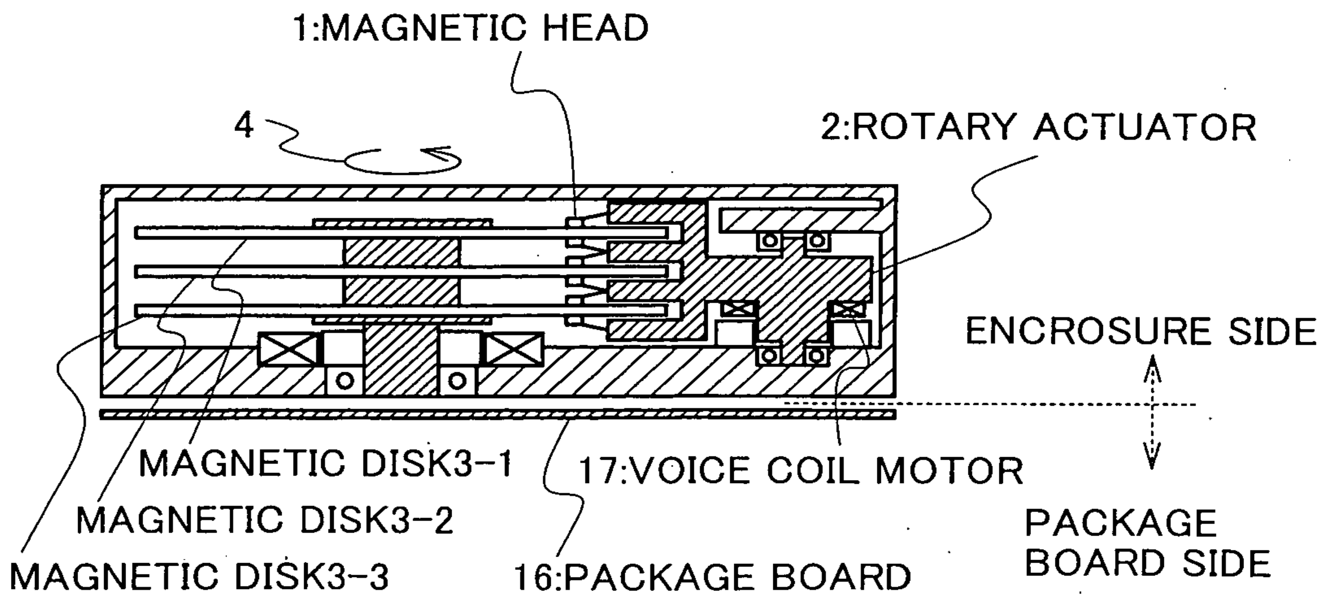

1:MAGNETIC HEAD
4
2:ROTARY ACTUATOR
ENCROSURE SIDE
MAGNETIC DISK3-1
17:VOICE COIL MOTOR
MAGNETIC DISK3-2
PACKAGE
BOARD SIDE
MAGNETIC DISK3-3
16:PACKAGE BOARD

FIG. 5

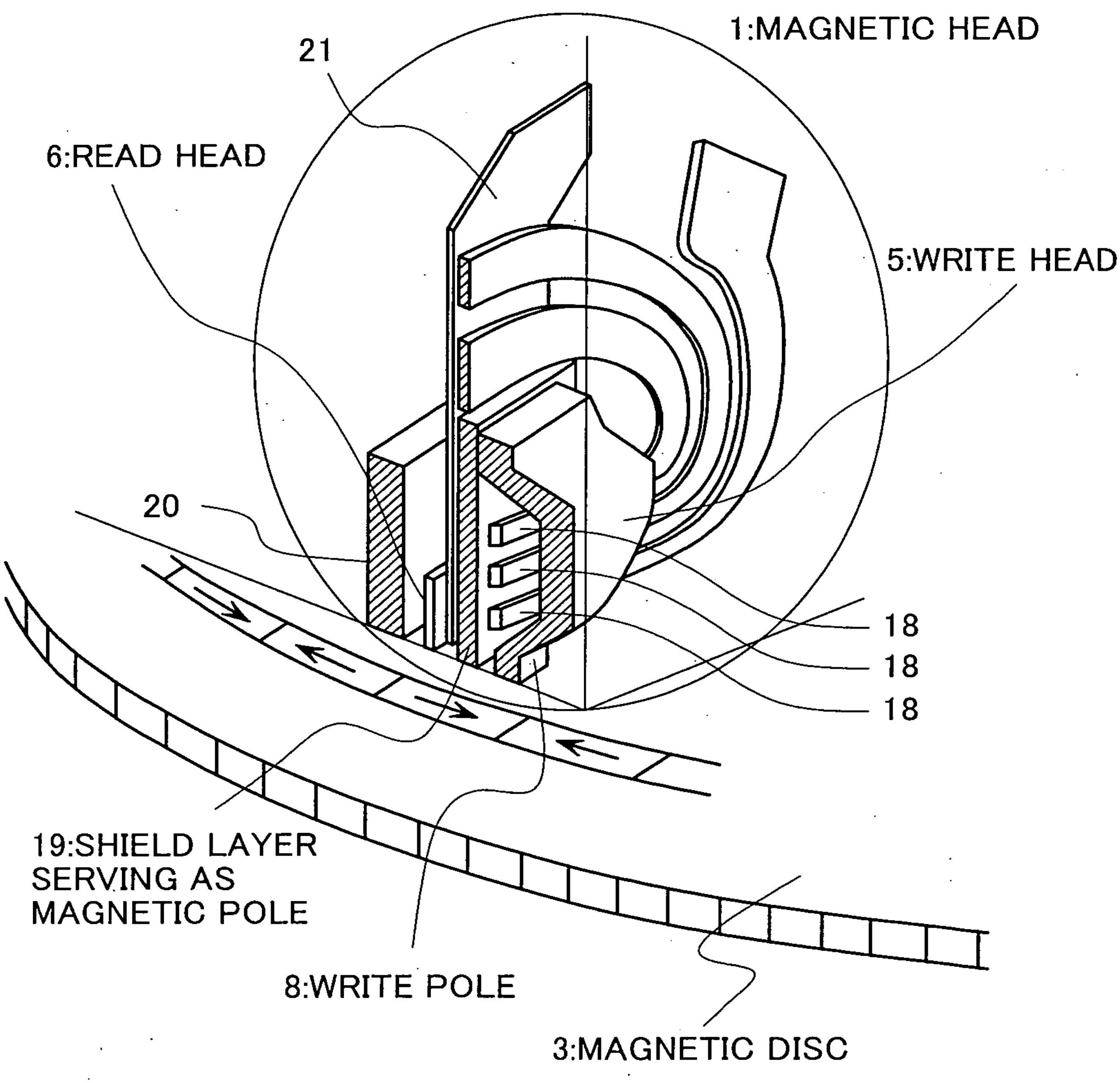

1:MAGNETIC HEAD
21
6:READ HEAD
5:WRITE HEAD
20
18
18
18
19:SHIELD LAYER
SERVING AS
MAGNETIC POLE
8:WRITE POLE
3:MAGNETIC DISC

FIG. 6A

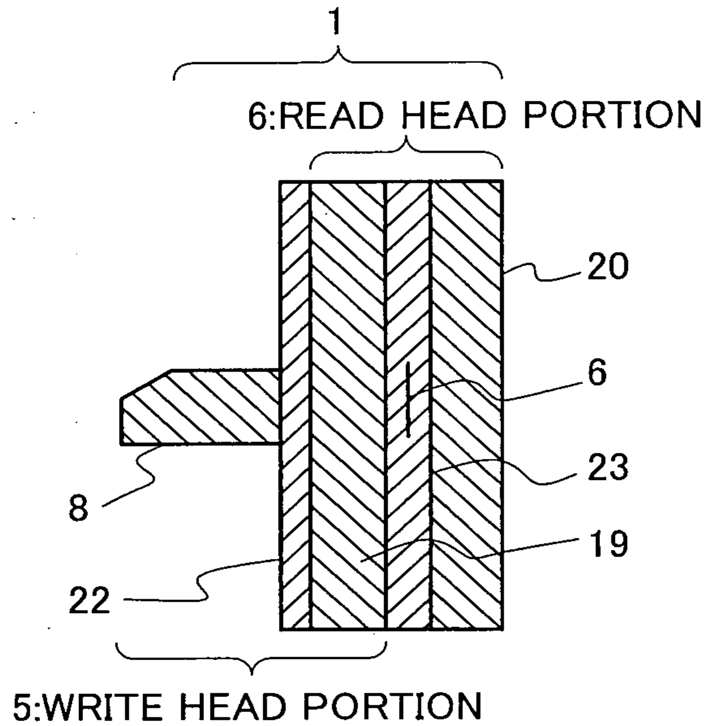

1
6:READ HEAD PORTION
20
6
23
8
19
22
5:WRITE HEAD PORTION

FIG. 6B

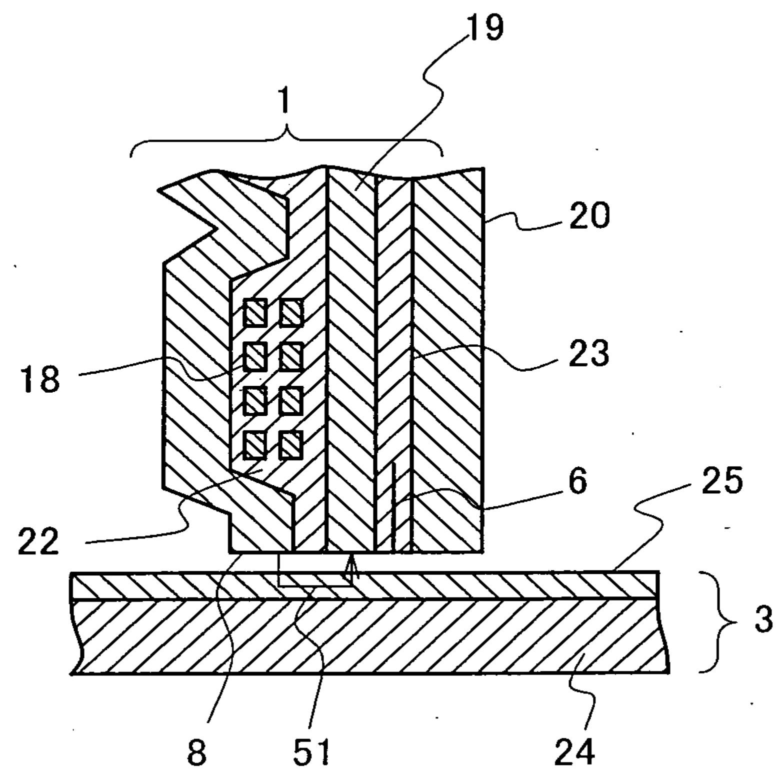

19
1
20
18
23
6
25
22
3
8
51
24

FIG. 7

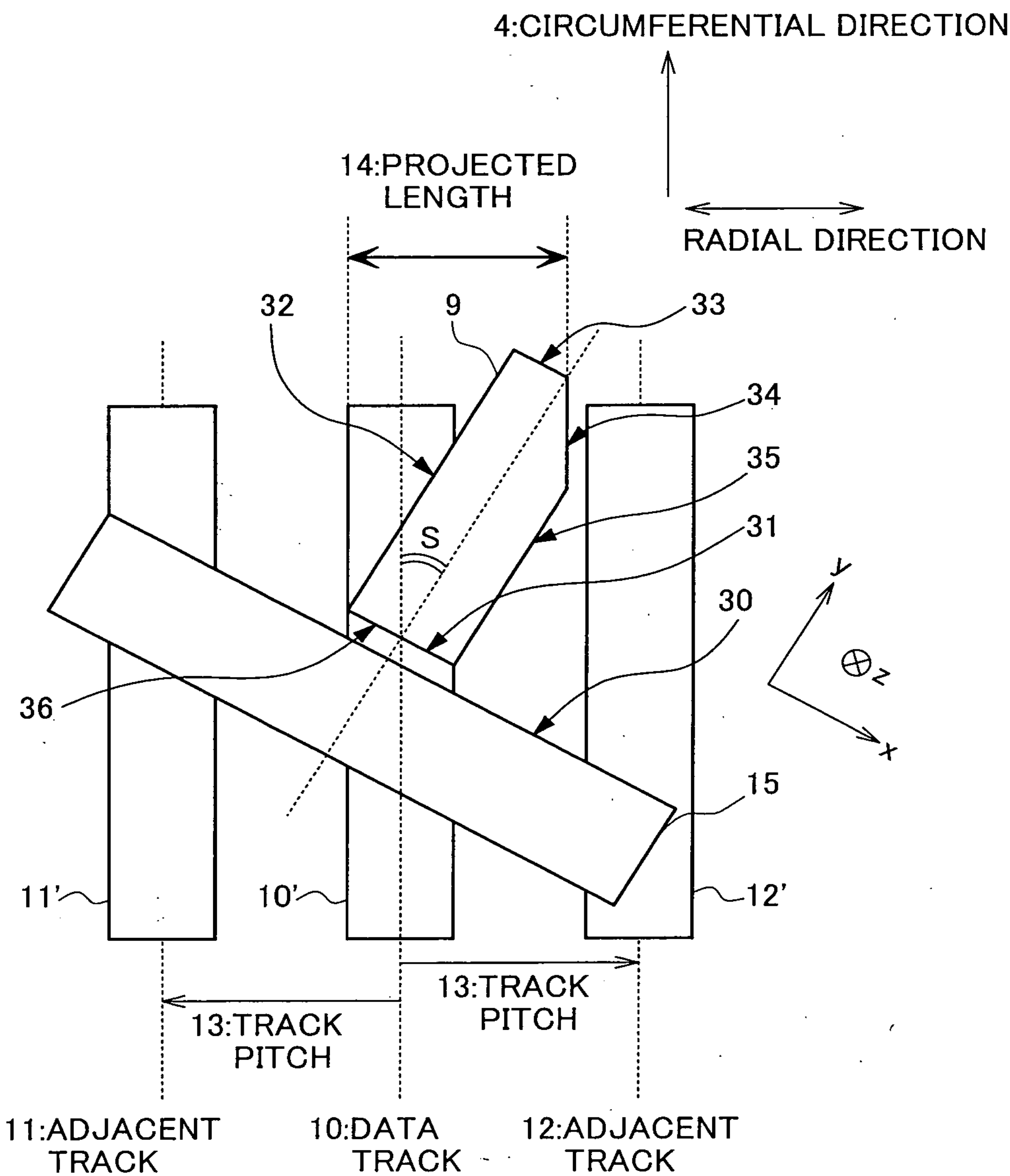

4:CIRCUMFERENTIAL DIRECTION
14:PROJECTED LENGTH
RADIAL DIRECTION
32
9
33
34
35
31
30
S
y
z
x
36
15
11'
10'
12'
13:TRACK PITCH
13:TRACK PITCH
11:ADJACENT TRACK
10:DATA TRACK
12:ADJACENT TRACK

FIG. 8

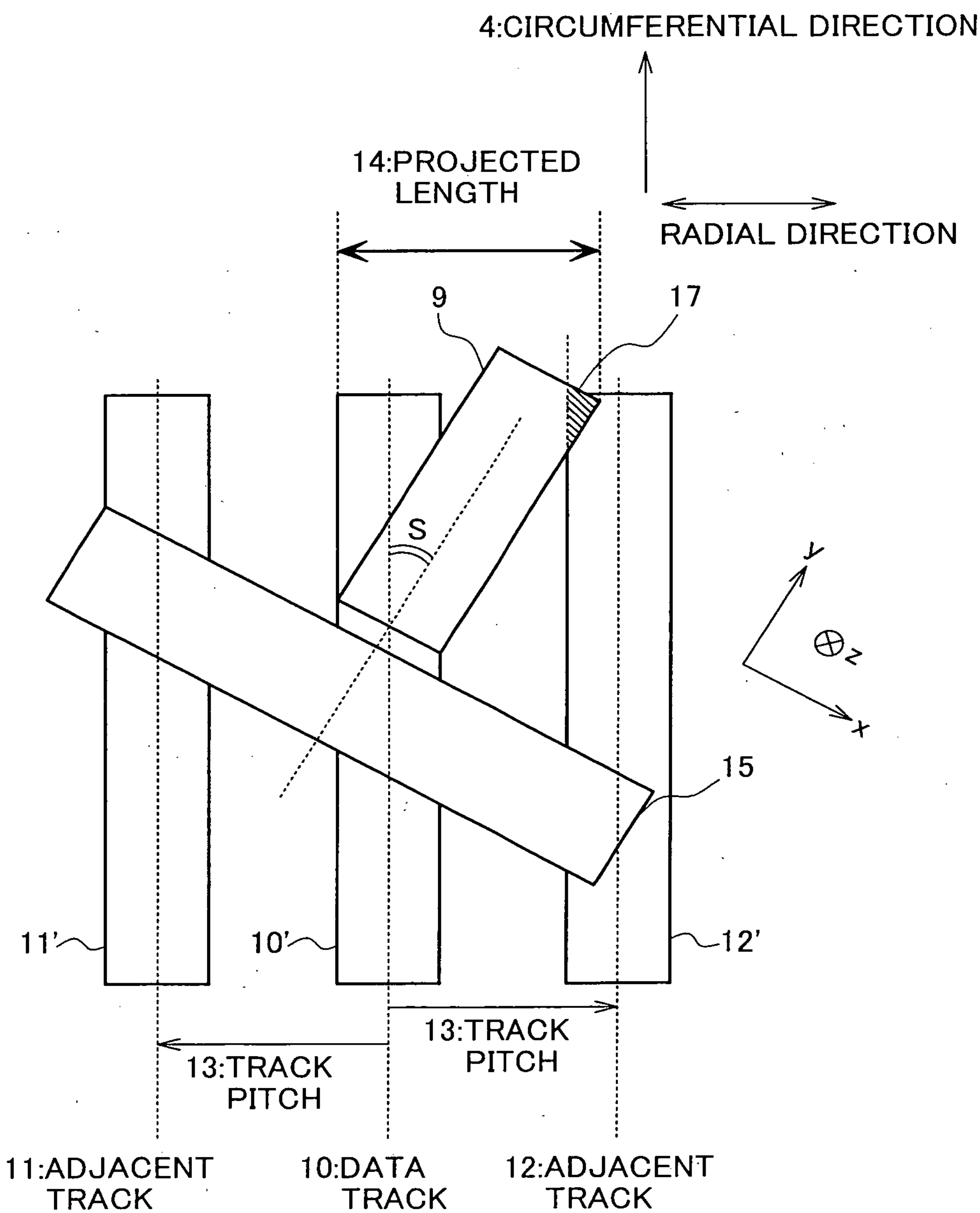
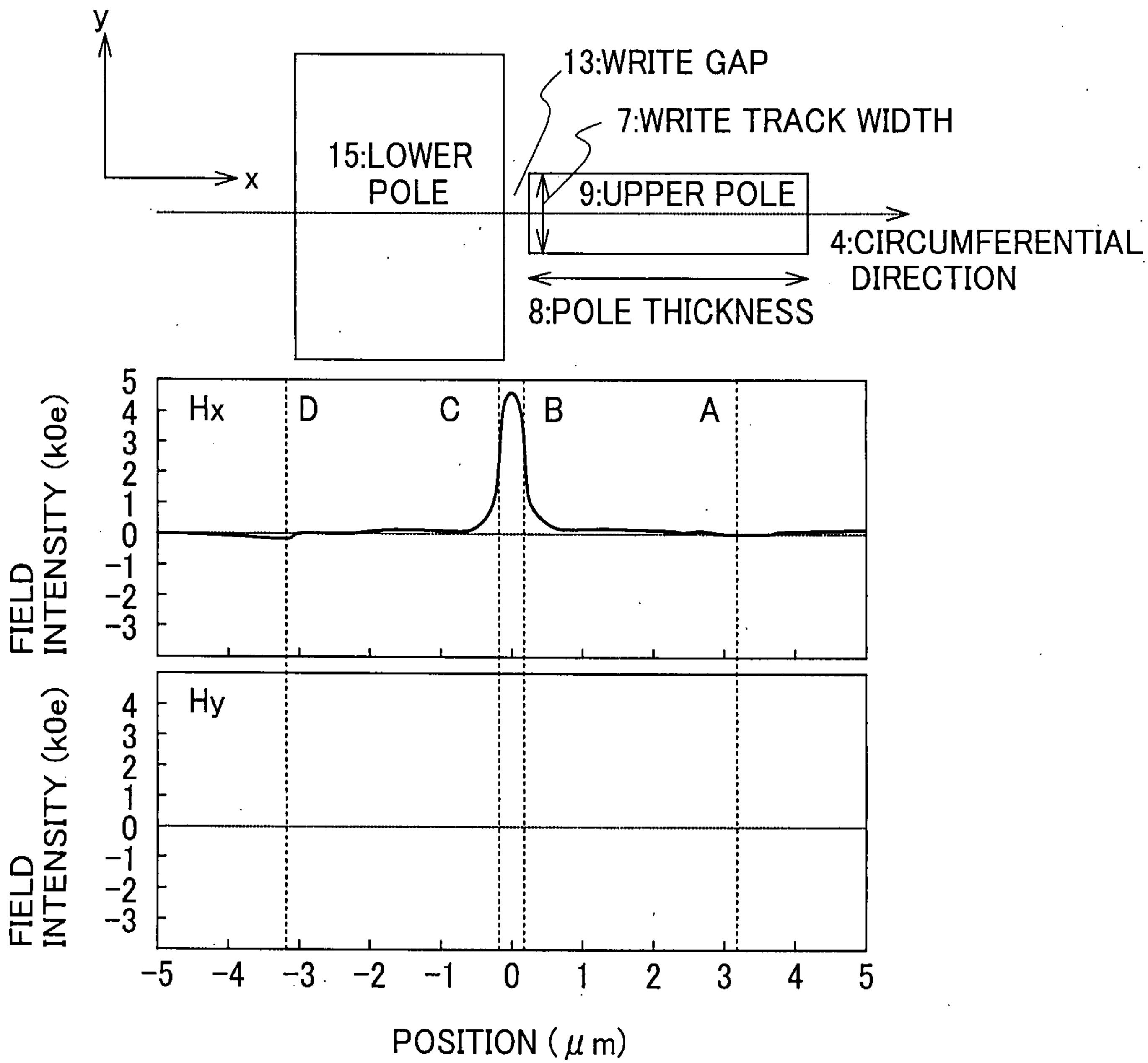
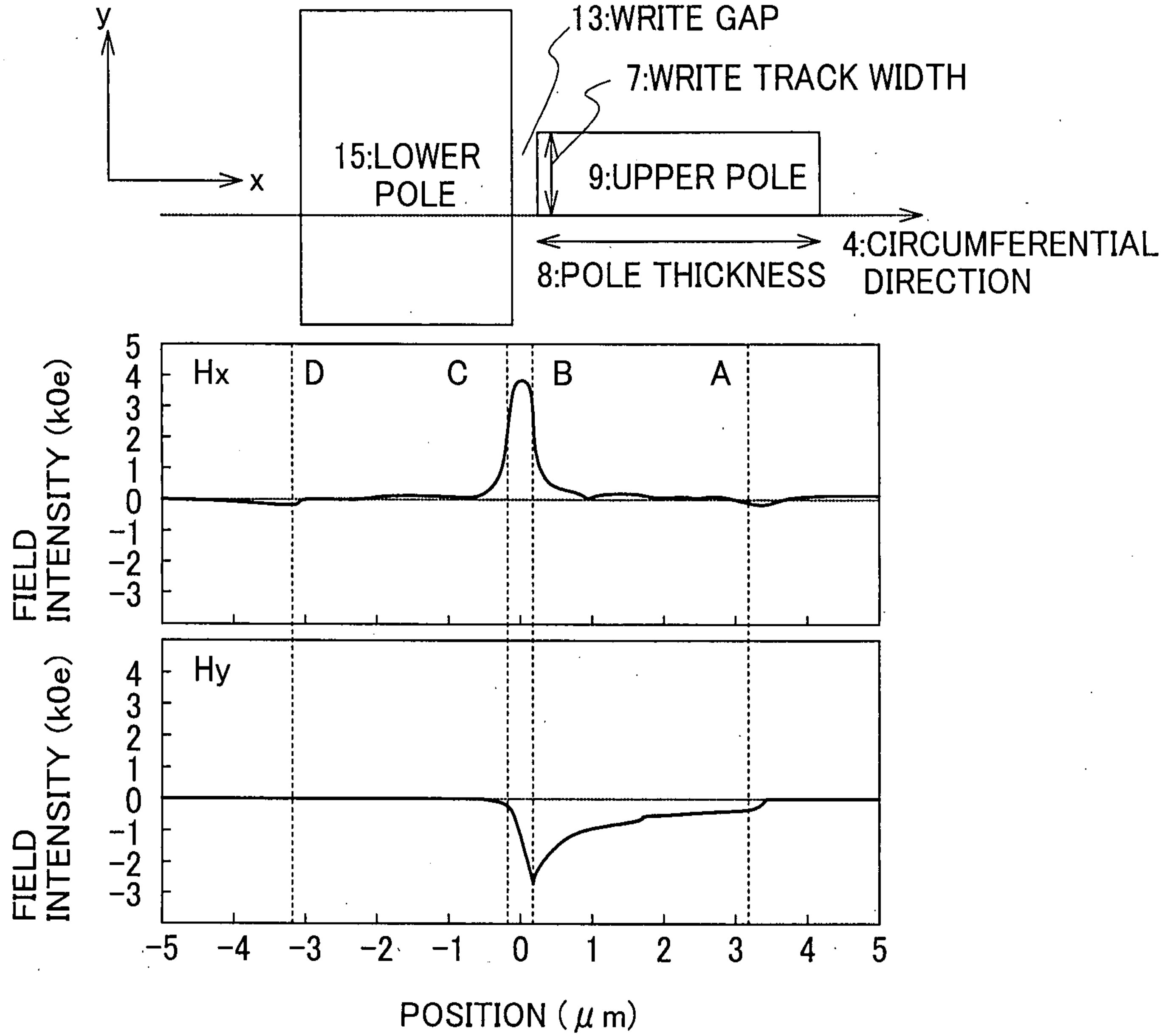

4:CIRCUMFERENTIAL DIRECTION
14:PROJECTED LENGTH
RADIAL DIRECTION
9
17
S
y
z
x
15
11'
10'
12'
13:TRACK PITCH
13:TRACK PITCH
11:ADJACENT TRACK
10:DATA TRACK
12:ADJACENT TRACK

FIG. 9



y
x
15:LOWER POLE
13:WRITE GAP
7:WRITE TRACK WIDTH
9:UPPER POLE
4:CIRCUMFERENTIAL DIRECTION
8:POLE THICKNESS
Hx
D
C
B
A
Hy
FIELD INTENSITY (k0e)
FIELD INTENSITY (k0e)
5
4
3
2
1
0
−1
−2
−3
−5
−4
−3
−2
−1
0
1
2
3
4
5
POSITION (μm)

FIG. 10



y
x
15:LOWER POLE
13:WRITE GAP
7:WRITE TRACK WIDTH
9:UPPER POLE
8:POLE THICKNESS
4:CIRCUMFERENTIAL DIRECTION
Hx
Hy
D
C
B
A
FIELD INTENSITY (kOe)
FIELD INTENSITY (kOe)
5 4 3 2 1 0 −1 −2 −3
4 3 2 1 0 −1 −2 −3
−5 −4 −3 −2 −1 0 1 2 3 4 5
POSITION (μm)

FIG. 11

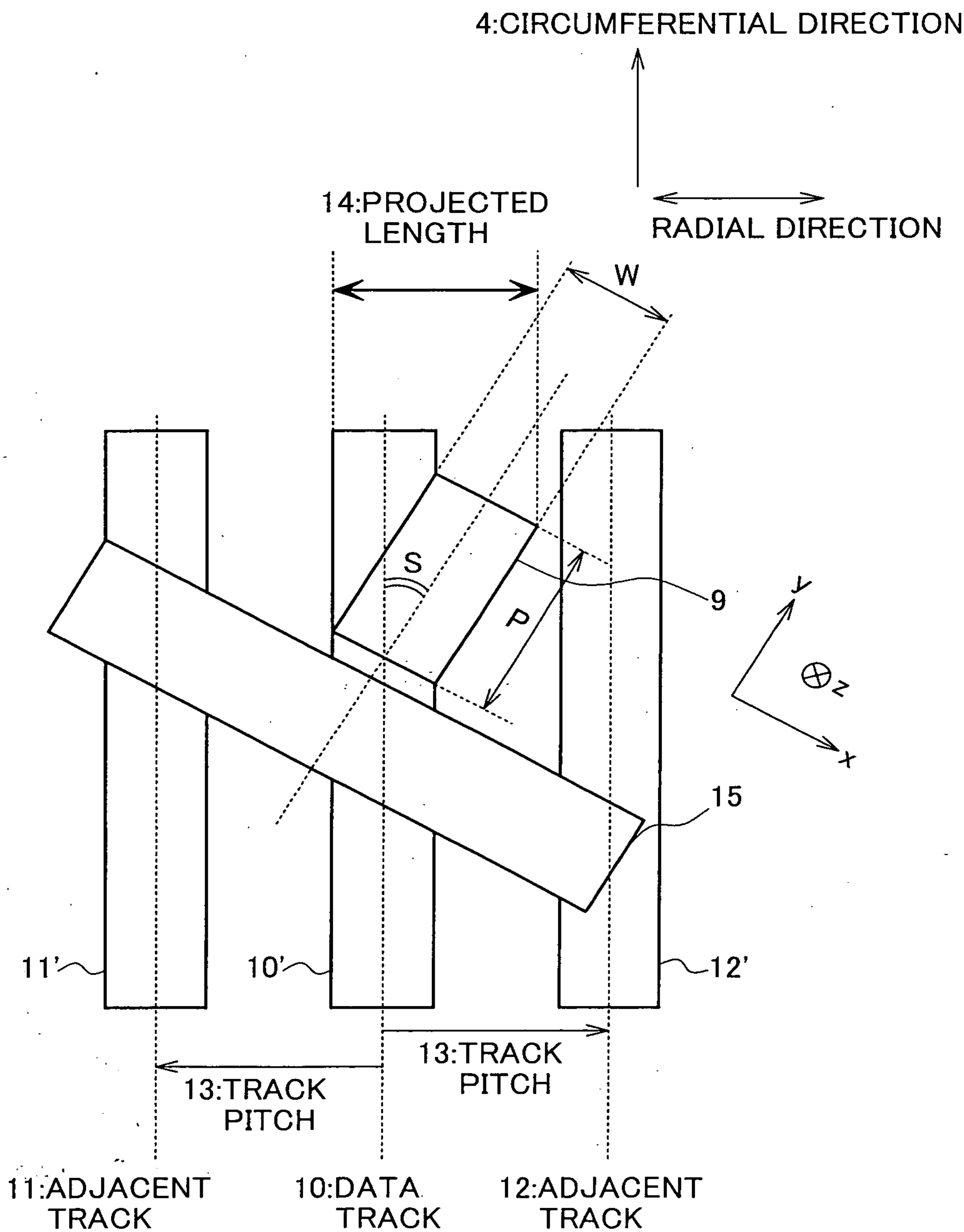

4:CIRCUMFERENTIAL DIRECTION
RADIAL DIRECTION
14:PROJECTED LENGTH
W
S
P
9
y
z
x
15
11'
10'
12'
13:TRACK PITCH
13:TRACK PITCH
11:ADJACENT TRACK
10:DATA TRACK
12:ADJACENT TRACK

FIG. 12

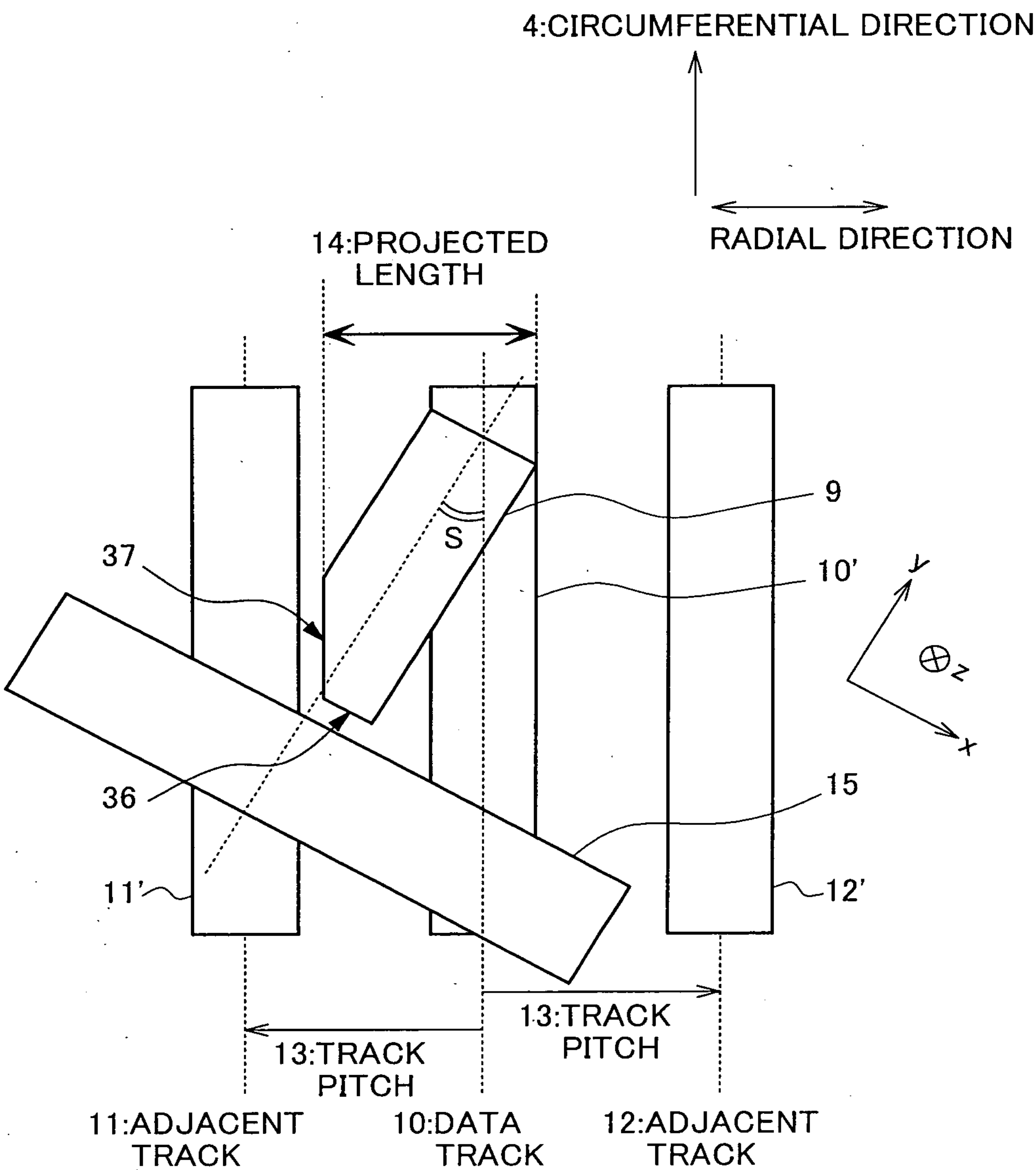

4:CIRCUMFERENTIAL DIRECTION
RADIAL DIRECTION
14:PROJECTED LENGTH
9
S
37
10'
y
z
x
36
15
11'
12'
13:TRACK PITCH
13:TRACK PITCH
11:ADJACENT TRACK
10:DATA TRACK
12:ADJACENT TRACK

FIG. 13

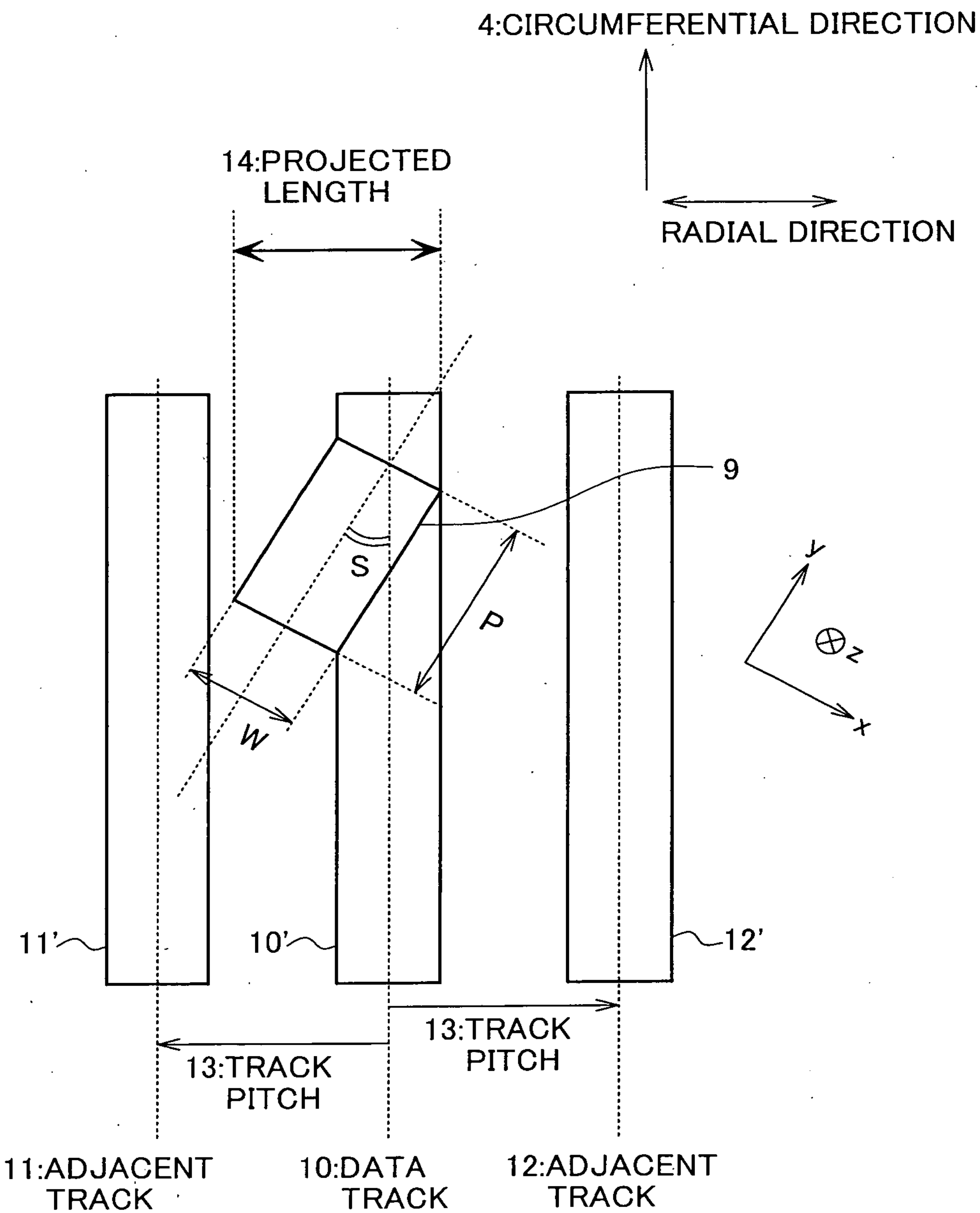

4:CIRCUMFERENTIAL DIRECTION
RADIAL DIRECTION
14:PROJECTED LENGTH
9
S
P
W
y
z
x
11'
10'
12'
13:TRACK PITCH
13:TRACK PITCH
11:ADJACENT TRACK
10:DATA TRACK
12:ADJACENT TRACK

FIG. 14

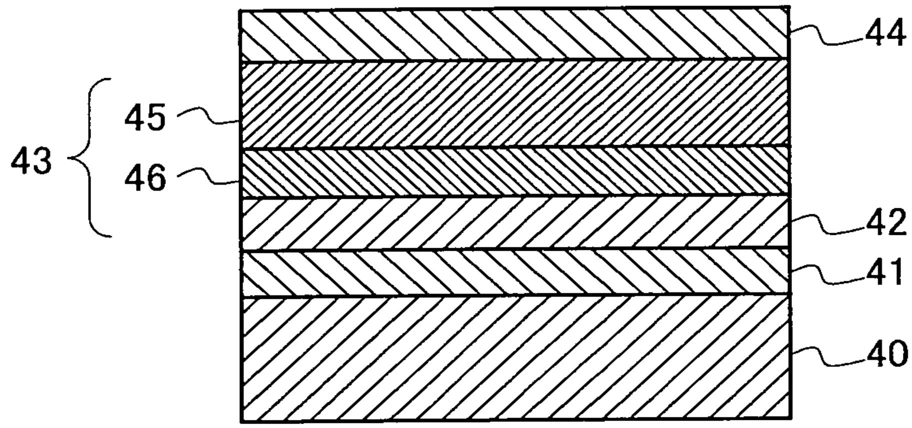

44
45
43
46
42
41
40

FIG. 15

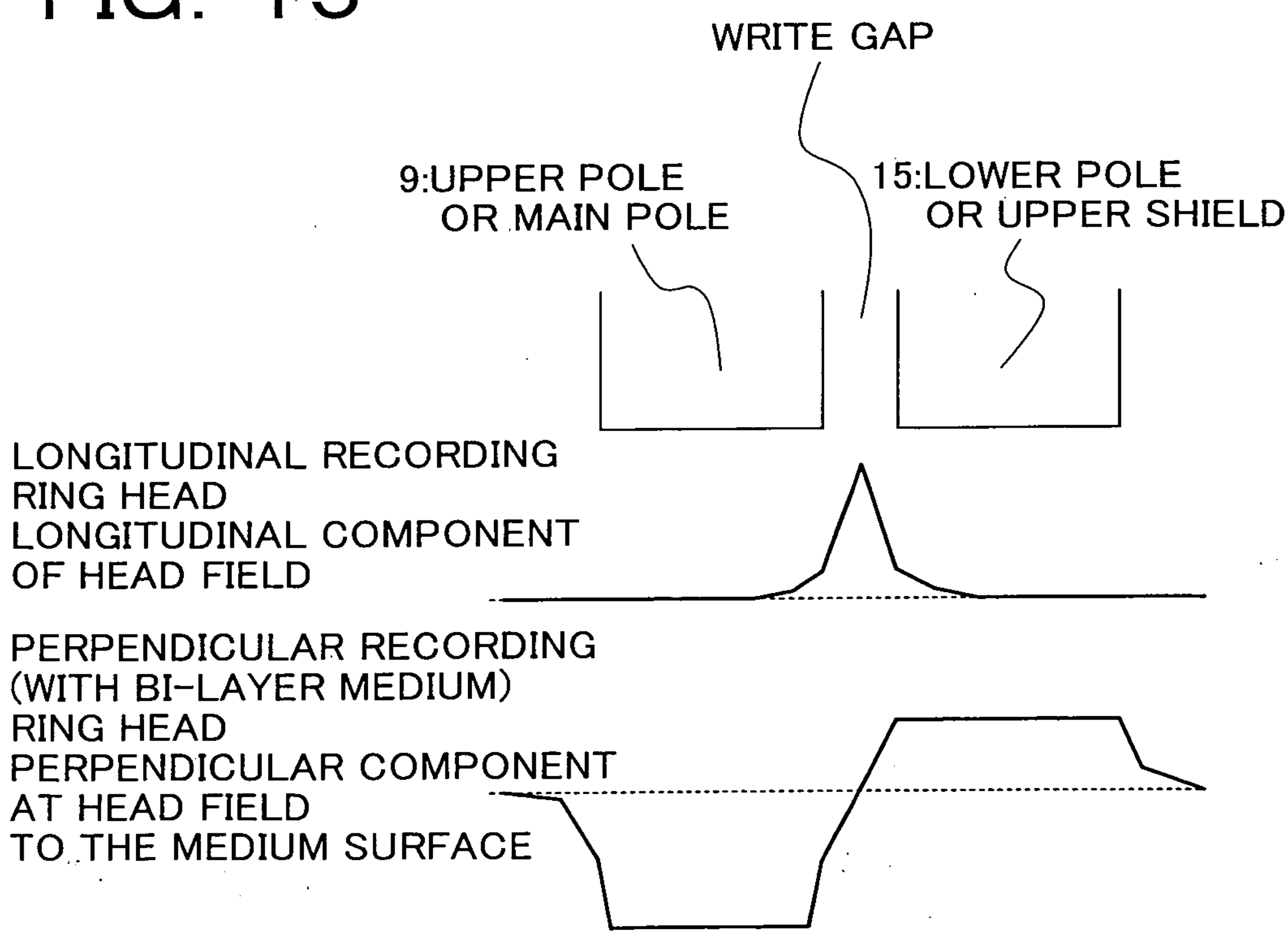

WRITE GAP
9:UPPER POLE
OR MAIN POLE
15:LOWER POLE
OR UPPER SHIELD
LONGITUDINAL RECORDING
RING HEAD
LONGITUDINAL COMPONENT
OF HEAD FIELD
PERPENDICULAR RECORDING
(WITH BI-LAYER MEDIUM)
RING HEAD
PERPENDICULAR COMPONENT
AT HEAD FIELD
TO THE MEDIUM SURFACE

FIG. 16A

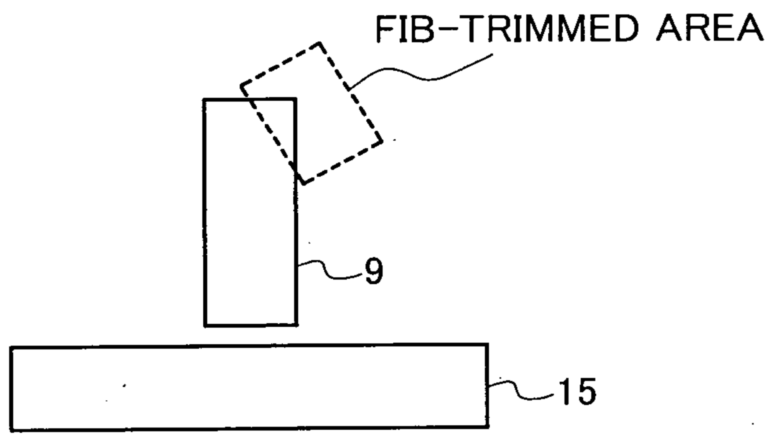


FIG. 16B

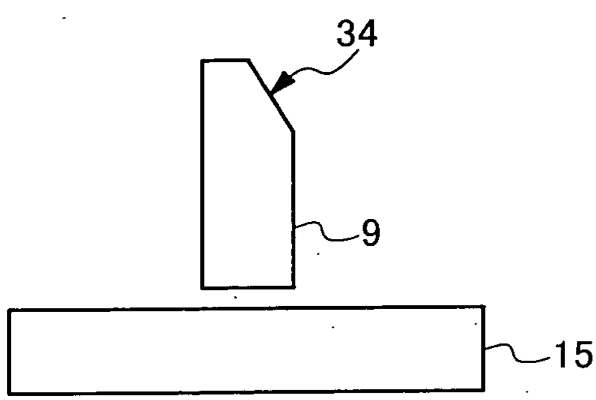


FIG. 17A

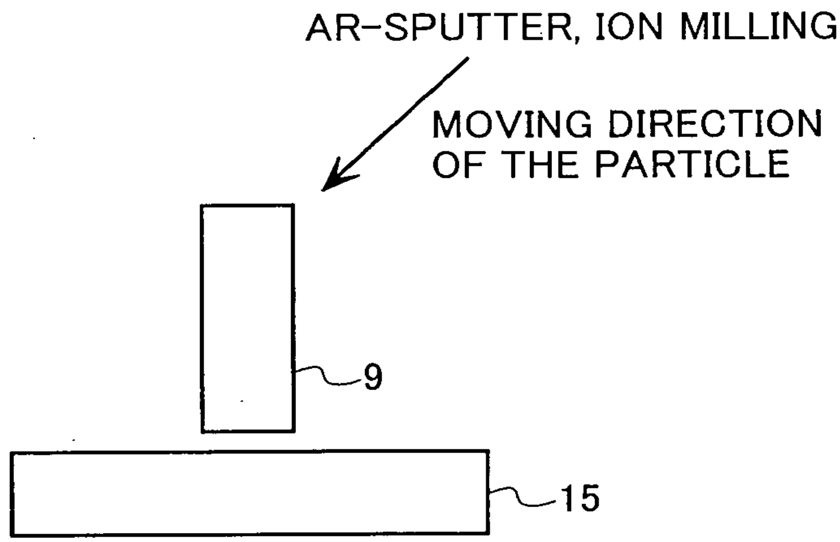


FIG. 17B

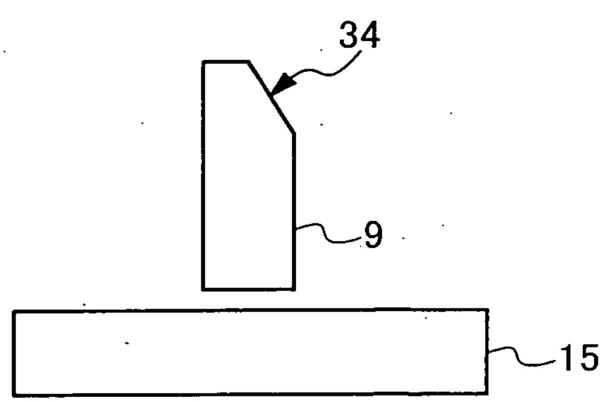


FIG. 18A

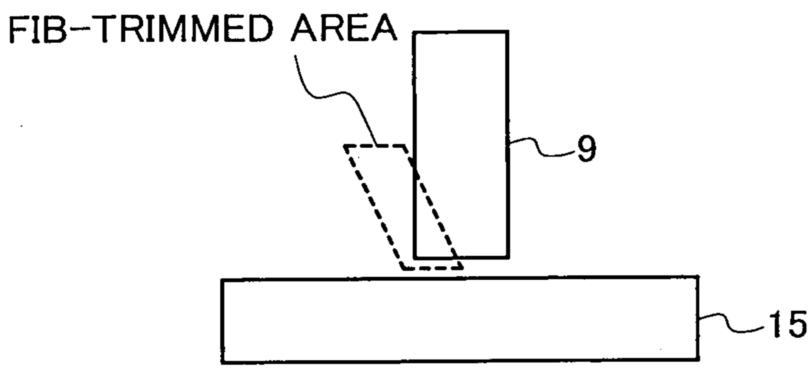


FIG. 18B

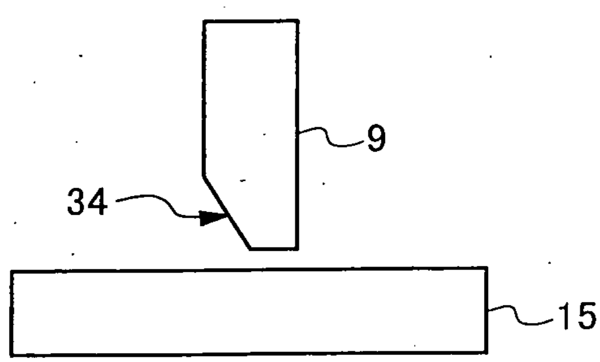


FIG. 19A

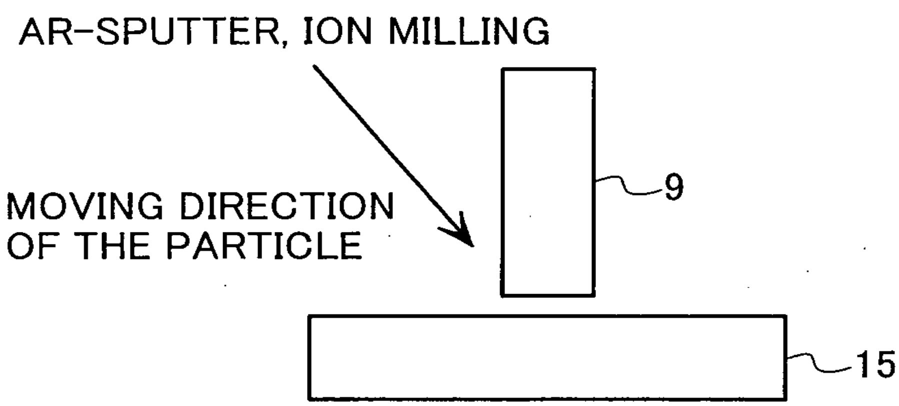


FIG. 19B

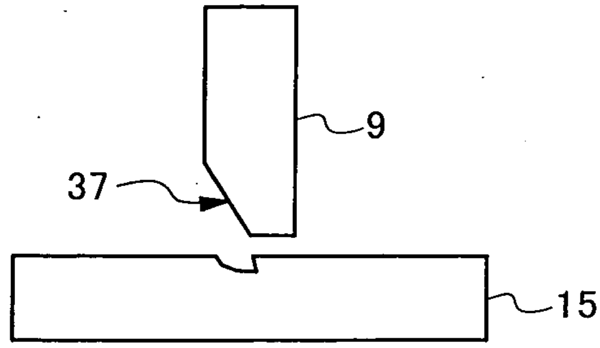


FIG. 20

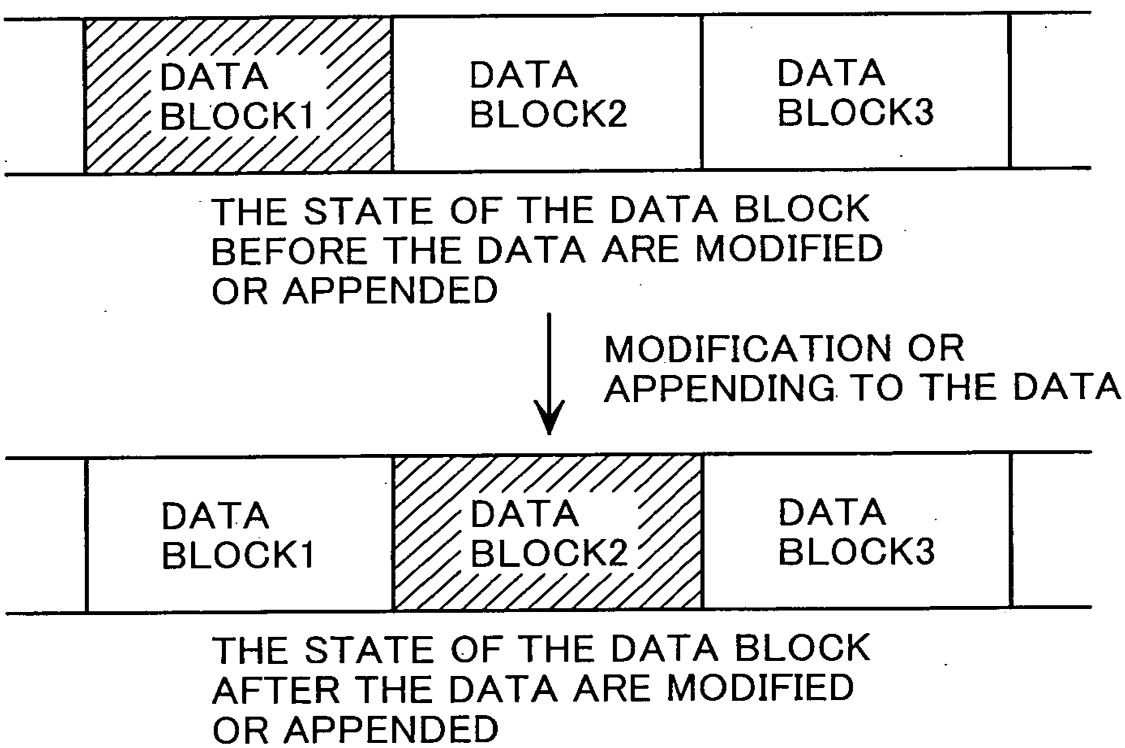
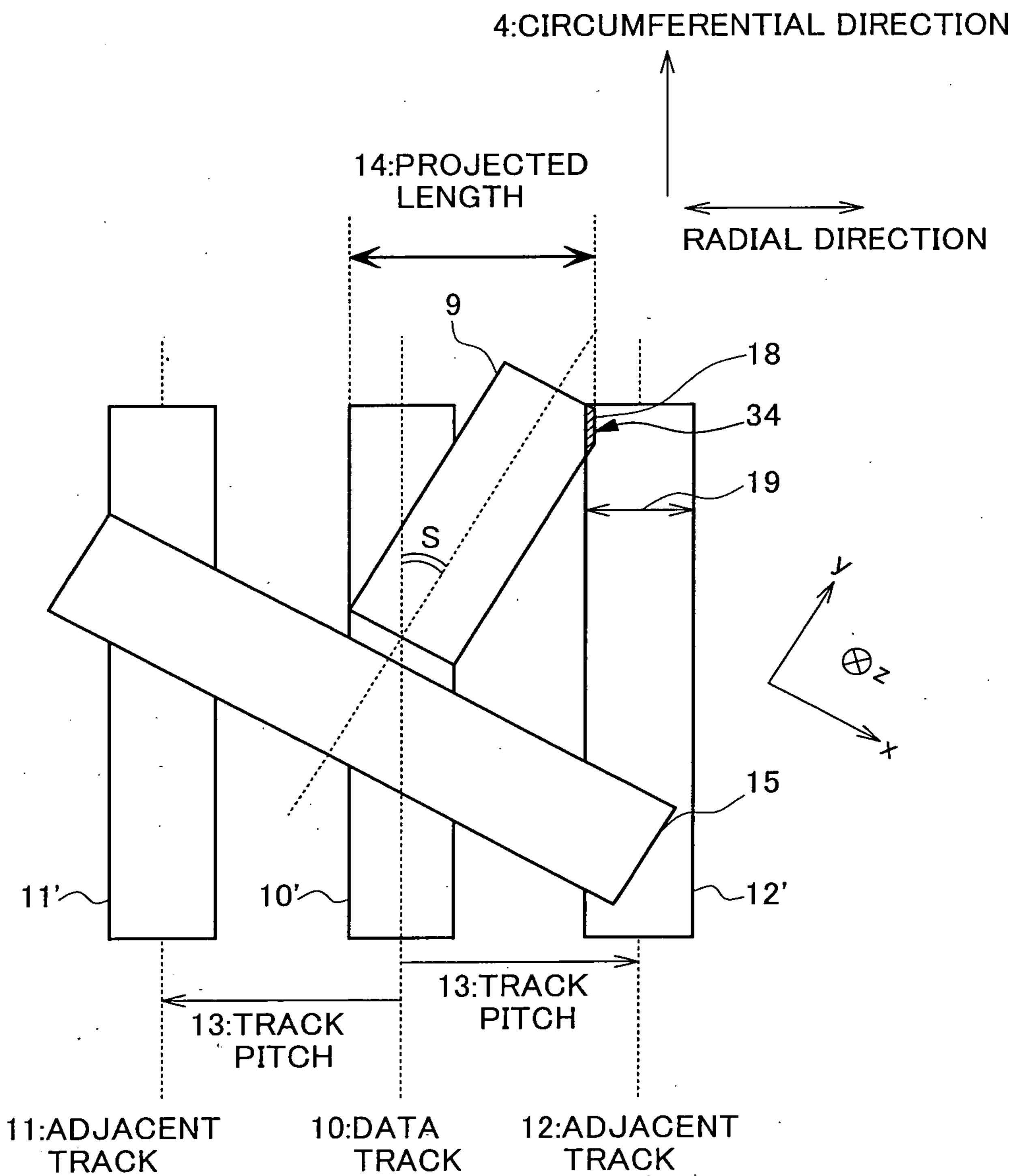

DATA
BLOCK1
DATA
BLOCK2
DATA
BLOCK3
THE STATE OF THE DATA BLOCK
BEFORE THE DATA ARE MODIFIED
OR APPENDED
MODIFICATION OR
APPENDING TO THE DATA
DATA
BLOCK1
DATA
BLOCK2
DATA
BLOCK3
THE STATE OF THE DATA BLOCK
AFTER THE DATA ARE MODIFIED
OR APPENDED

FIG. 21


4:CIRCUMFERENTIAL DIRECTION
14:PROJECTED LENGTH
RADIAL DIRECTION
9
18
34
19
S
y
z
x
15
11'
10'
12'
13:TRACK PITCH
13:TRACK PITCH
11:ADJACENT TRACK
10:DATA TRACK
12:ADJACENT TRACK